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ARTICLE

Dispersion mapping of Carbon Monoxide (CO) derived Sentinel 5P and evaluation with LUR model during winter in Ulaanbaatar, Mongolia

***Odbaatar Enkhjargal*[1,2,*], Davaagatan Tuyagerel[2], Renchinmyadag Tovuudorj[2], Zolzaya Khurelsukh[2] and Enkhmaa Sarangerel[3]**

[1]Department of Environmental Science, School of Environmental Science and Engineering, Tianjin University, Tianjin, P.R. China

[2]Division of Physical Geography and Environmental Research, Institute of Geography and Geoecology, Mongolian Academy of Sciences, Ulaanbaatar, Mongolia

[3]Division of Environmental Monitoring Network, National Agency for Meteorology and Environmental Monitoring, Ulaanbaatar, Mongolia

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Abstract: In recent years, air pollution caused by coal combustion in Ulaanbaatar city is becoming a priority health concern for the city residents and many researchers are investigating its ingredient and impact on people's health. This study aims to map Carbon Monoxide (CO) dispersion from remote sensing data during the winter season and evaluate it with the Land Use Regression (LUR) model result and fixed station measurements. Fixed station data from the National Agency for Meteorological and Environmental Monitoring (NAMEM) were utilized as a reference point for remote sensing data, a dependent variable for LUR model. Sentinel 5P TROPOMI CO data was correlated moderately-positive with fixed station measurements (R=0.56). And LUR model performance was relatively higher compared to Sentinel data or its determination coefficient R2=0.71, Adjusted R2=0.53, Root Mean Square Error (RMSE)=0.84 mg/m3 and Mean Absolute Error (MAE)=0.7 mg/m3. These statistical evaluation coefficients are relatively lower than other similar studies, and authors have adduced it to a lack of reference data and satellite data spatial resolution. Finally, these two result maps were compared, which have shown lower correlation-positive or R=0.44. Even though these two map results are not exactly the same, Pearson's correlation coefficient shows that both image results move in the same direction or they are moderately showing the same results.

Keywords: *Carbon Monoxide, Sentinel 5P TROPOMI, LUR model, Ulaanbaatar city;*

INTRODUCTION

Air quality is a crucial factor for the mental and physical health of urban residents. With each passing year, air pollution has been on the rise in urban areas, particularly in major cities. Consequently, there is a need to monitor air pollution quality and its dispersion. Even though many stationary stations have been set up in order to measure air pollution in the cities, they are,

***Corresponding author, email**: odbaatare@mas.ac.mn* https://orcid.org/0000-0001-93610753

however, not cost effective and cannot cover large areas. So, researchers have been trying to find a cost-effective method to measure air pollution over large area, and many satellite data are being experienced widely for air pollution monitoring. Of these, Sentinel 5P TROPOMI sensor is trying to monitor each air pollutant, such as CO (Carbon Monoxide), NO_2 (Nitrogen dioxide) etc. [1]. Thus, many researchers are also using this sensor data for air pollution study. For instance, Vahid Safarianzengir et al [2] and Arfani Priyambodo et al [3] used Sentinel 5PTROPOMI data for CO dispersion analysis in the atmosphere, and their results show that CO dispersion data from Sentinel 5P TROPOMI sensor tends to positively correlate with large cities and main roads. From this, we can presume that Sentinel 5P TROPOMI CO data is better for air pollution dispersion study.

In recent decades, air pollution in the city of Ulaanbaatar became a priority concern for Mongolian authorities. Air pollution in Ulaanbaatar mainly originates from coal combustion in the “Ger” (Mongolian traditional round felt dwelling) areas during the winter season and pollution from fine particulate matter ($PM_{2.5}$) exceeds 27.5 times the “WHO Air Quality Guideline: Particulate Matter” levels [4] and 8.2 times higher than the “Air Quality General Requirement” levels specified in the Mongolian standard MNS4585:2016 [5].

Ulaanbaatar is the capital city of Mongolia and is the most crowded city in the country and the coldest capital city in the world [6]. In other words, approximately one half of the total population of the country (43.6%) is living in Ulaanbaatar, and about one half of the Ulaanbaatar households (51.3%) live in the ger areas, where infrastructure, especially heating system [7], is not developed adequately. Thus, households in the ger areas use coal-burning stoves as a heating device, which emits many different types of air pollutants, such particulate matters carbon monoxide, carbon dioxide etc. According to NAMEM (National Agency for Meteorology and Environmental Monitoring) report, 3,751 thermal boilers (15-100kW) [8] and 200,941 coal stoves emit smoke in Ulaanbaatar [7]. And another factor that contributes to increasing air pollution is the city's topographic condition, as the city is located in the Tuul river valley basin, surrounded on all founds by hills and by mountains, which contributes to the accumulation of air pollution in the city center. According to a study on Landform classification of Ulaanbaatar city, approximately 80% of the total territory of Ulaanbaatar is mountainous [9] and the mountains surrounding the city are blocking air movement and thus, contributing to air pollution accumulation.

At present, NAMEM and the Department of Municipal Air Quality (DMAQ) are jointly managing 18 fixed-monitoring stations and are measuring air quality data every minute and are recording averaged data between 15-60 minutes every day. Data from these stations are the main reference points for air quality research and only 14 of these 18 fixed stations are measuring CO (Figure 1).

As mentioned above, although air pollution is increasingly extensively in Ulaanbaatar, the fixed stations that measure air quality are too few and far apart. Therefore, accurate air pollution mapping approach is still needed for air quality dipersion research and a number of researchers have been trying to understand air pollution dispersion with varied approaches [10], [11], [12], [13], [14]. Of these, only Gantuya Ganbat et al [13] have used the Sentinel 5P TROPOMI remote sensing approach for NO_2 dispersion in Ulaanbaatar.

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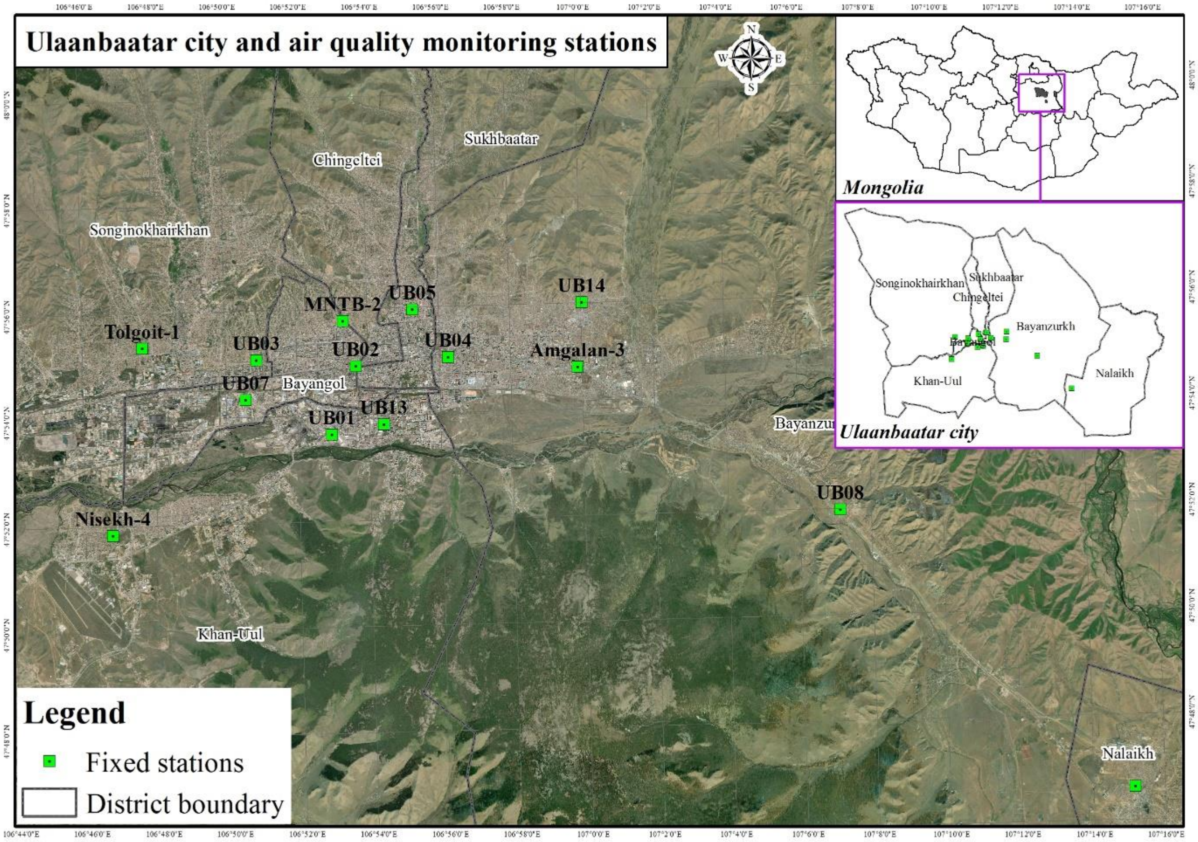

Figure 1. Study area and monitoring stations

Other researchers have used statistical methods for particulate matter pollution, however, not all the results are accurate. As part of an effort to precisely map the dispersion of $PM_{2.5}$ pollutant, we developed a statistical method LUR (Land Use Regression) model for $PM_{2.5}$ dispersion in our previous study [15], and its RMSE and validation coefficients were comparatively higher. In this study, remote sensing data and statistical method were both employed for CO dispersion analysis.

Finally, the aim of this study is to find better method for CO dispersion mapping, which we believe is a first step towards mapping Ulaanbaatar city's CO dispersion using remote sensing data, and secondly, the objective is to map this dispersion using the LUR model, and finally, to compare their performance.

MATERIALS AND METHODS

With increasing air pollution and its negative impact on the health of the city inhabitants, researchers have been constantly seeking better methods to monitor its dispersion as accurately as possible. Remote sensing data, monitoring station data, statistical methods and many models have been applied widely for air pollution dispersion. So, in order to map CO dispersion in Ulaanbaatar city, remote sensing data, fixed stations data, and LUR model base data from previous studies have been used in this study. And these all data have been processed in ArcGIS and R statistical software leading to the production of CO dispersion maps.

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Data

Remote sensing data

Sentinel 5P TROPOMI sensor data has been used as remote sensing data in this study. TROPOMI instrument onboard Sentinel-5 Precursor uses a passive remote sensing technique and TROPOMI clear sky observations provide CO total columns with spatial resolution of 7.0*5.5 kilometer, and it retrieves the CO global abundance exploiting clear-sky and cloudy-sky Earth radiance measurements in the 2.3 µm spectral range of the shortwave infrared (SWIR) part of the solar spectrum [16] and recently, many researchers have been attempting to map air pollution dispersion using this sensor data [17] [18]. In order to map dispersion of CO, Sentinel-5P TROPOMI data or 90 images starting to 1 December 2022 to 28 February 2023 were downloaded and seasonal average dispersion in ArcGIS were calculated.

Fixed station data and Land use data

Measurement data from fixed stations and Land Use Data have been utilized for Land Use Regression model as Dependent and Independent variables, and the results from this model were used as a reference point for Sentinel5P TROPOMI result. Data from fixed stations have been taken from NAMEM and DMAQ. At present, there are a total of 18 monitoring stations operating on the territory of the city of Ulaanbaatar, and of these, 14 stations are regularly measuring CO (Figure 1) every minute and recording averaged data every 15 to 60 minutes. CO measurement data, starting from December 2022 to 28 February 2023, have been collected from these 14 stations and they have been averaged as CO pollution in winter time.

Land Use Data with 100 m spatial resolution, such as *Ger* (ger density), *baishin* (wooden, brick or concrete house density), *road* (main road density), *agri* (agricultural land with buffer 50 m), *stoves* (boilers only for heating) were taken from previous study, which developed LUR model for $PM_{2.5}$ in Ulaanbaatar city [15], because, $PM_{2.5}$ and CO fixed station measurements are highly correlated to each other. In other words, CO concentration was correlated with $PM_{2.5}$ concentration on fixed stations, and especially correlation of ger area stations were higher. For instance, Amgalan (R=0.89), MNTB (R=0.88), Tolgoit (R=0.68), Nisekh (R=0.88) [19] etc. Therefore, this model with a fundamental data with 100 m spatial resolution is particularly suitable for CO dispersion LUR model in Ulaanbaatar city, and researchers have applied this model without any modification.

Calculation of monthly average dispersion. Sentinel 5P Tropomi instrument data is too coarse or its spatial resolution is 7.5*5.5 km. In order to increase the resolution, spatial resolution has been resampled with 100 meter grid cells and seasonal average dispersion have been calculated. Its formula is as follows.

$$X_{mean} = \frac{(x_1 + x_2 + x_3 \ldots + x_n)}{n} \quad (1)$$

X_{mean}– Average value of cell
$X_{1,2,3\ \ldots n}$– Each cell value of image
n - amount of images

Land Use Regression model. In order to evaluate CO dispersion map, calculated from the Sentinel 5P TROPOMI, LUR model which were developed by Odbaatar et al [15] for $PM_{2.5}$ in Ulaanbaatar, have been adopted. CO over the Ulaanbaatar city mainly originates from coal combustion and it is related to fine particulate matter pollution dispersion that originates from incomplete coal combustion.

Thus, this model is available to use for CO dispersion over Ulaanbaatar city. So, all variables and model building were processed in R statistical software and final LUR model was defined as follows:

$$Y = 1.169 + 0.211 * Ger + 0.186 * baishin - 0.0007466 * road + 0.0001682 * agri + 0.0191 * stoves \quad (2)$$

After calculation of LUR model, a total of 146,211 grid points across the study region with 100 m in between each point were used. It is convenient to use the Inverse Distance Weighting [20] [21] approach to generate a surface map when working with a grid of equally spaced points, this is because each point's value may be extracted from the raster image as an individual value.

A model was then run using these point-independent values, making it possible to generate a high-resolution map using Equation 3 in ArcGIS:

$$Z_p = \frac{\sum_{t=1}^{n}(\frac{z_i}{d_i^p})}{\sum_{t=1}^{n}(\frac{1}{d_i^p})} \quad (3)$$

Z_p = value to be estimated;
Z_i= value to be estimated;
d_i^p = distance from the n data point to the power p of the point estimated.

Evaluation. In order to evaluate TROPOMI data result, LUR model, which is created with air pollution sources, has been used as a reference data. Because this LUR model has been developed for $PM_{2.5}$ dispersion in Ulaanbaatar city and the correlation between $PM_{2.5}$ and CO measurement on fixed stations are (Amgalan (R=0.89), MNTB (R=0.88), Tolgoit (R=0.68), Nisekh (R=0.88)) higher. Therefore, this model is convinient for CO dispersion map in Ulaanbaatar and it gives an opportunity to compare TROPOMI data result with the Pearson's correlation method.

RESULTS AND DISCUSSION

A total of 14 fixed station CO measurement values have been collected from NAMEM and DMAQ stations. Its descriptive statistics is shown in Table 1. All statistical parameters have been shown in this table, and standard error of sample is $0.44 mg/m^3$ or relatively lower. In other words, sample values are relatively close to each other. These measurement values from 14 stations are used as dependent value of CO LUR model.

Table 1. Descriptive statistics of Fixed station data (mg/m^3)

Mean	Standard Error	Median	Standard Deviation	Sample Variance	Range	Minimum	Maximum	Sum	Count
2.58	0.44	2.09	1.63	2.65	5.37	0.77	6.14	36.17	14.00

As a result, CO dispersion maps, including Sentinel 5P CO map and LUR model CO maps (Figure 2) were created. CO units in these two maps are denoted differently, caused by data sources. Sentinel 5P TROPOMICO map units was denoted by mol/m^3 according to Sentinel Hub-website [22] and the LUR model CO map units was denoted by $\mu g/m^3$ according to the "Air Quality General Requirement" standard specified in MNS4585:2016 [5]. So, these two different units have been utilized for the purpose of correlation.

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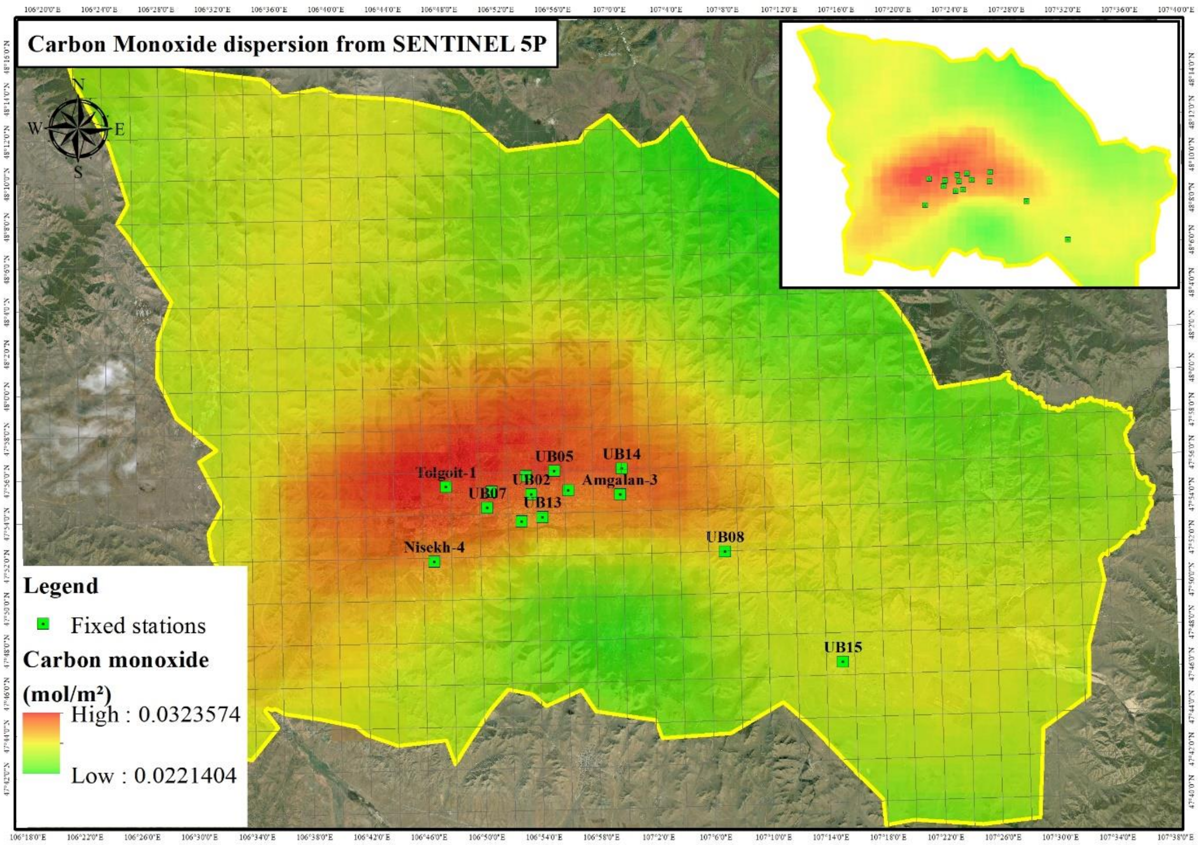
As for Sentinel 5P TROPOMI result, even though this map was created from satellite data with a resolution of 7.5*5.5 km, it generally covers residential areas, and especially its level is higher over the Ger areas such as Bayankhoshuu, Zuunsalaa and Tolgoit. CO dispersion is higher in north-west Ulaanbaatar and it is decreasing gradually and regularly from the Ger to non-residential areas. But, due to its resolution, it's CO dispersion is higher over some non-residential areas, such as Chingeltei mountain, Tuul river etc. This distribution map shows an extremely general result. Therefore, sentinel 5P TROPOMI CO data is not convenient for city level air pollution dispersion study. This result map correlated with the fixed station's measurements positive-moderately (R=0.56).

As for CO LUR model, CO dispersion is higher over the ger areas such as 7 Buudal, Bayan Khoshuu, First Khoroolol and Tolgoit. Due to CO LUR model based on air pollution source dispersion, it is relatively accurate as compared with the TROPOMI result map. CO LUR model result was evaluated with many statistical techniques, such as, Determination coefficient R^2=0.71, Adjusted Determination coefficient $R_{Adjusted}$=0.53, Root Mean Square Error RMSE=0.84 μg/m^3, Mean Absolute Error MAE=0.7 μg/m^3, respectively. According to this statistical analysis result, LUR model is available for use for CO dispersion map in Ulaanbaatar.



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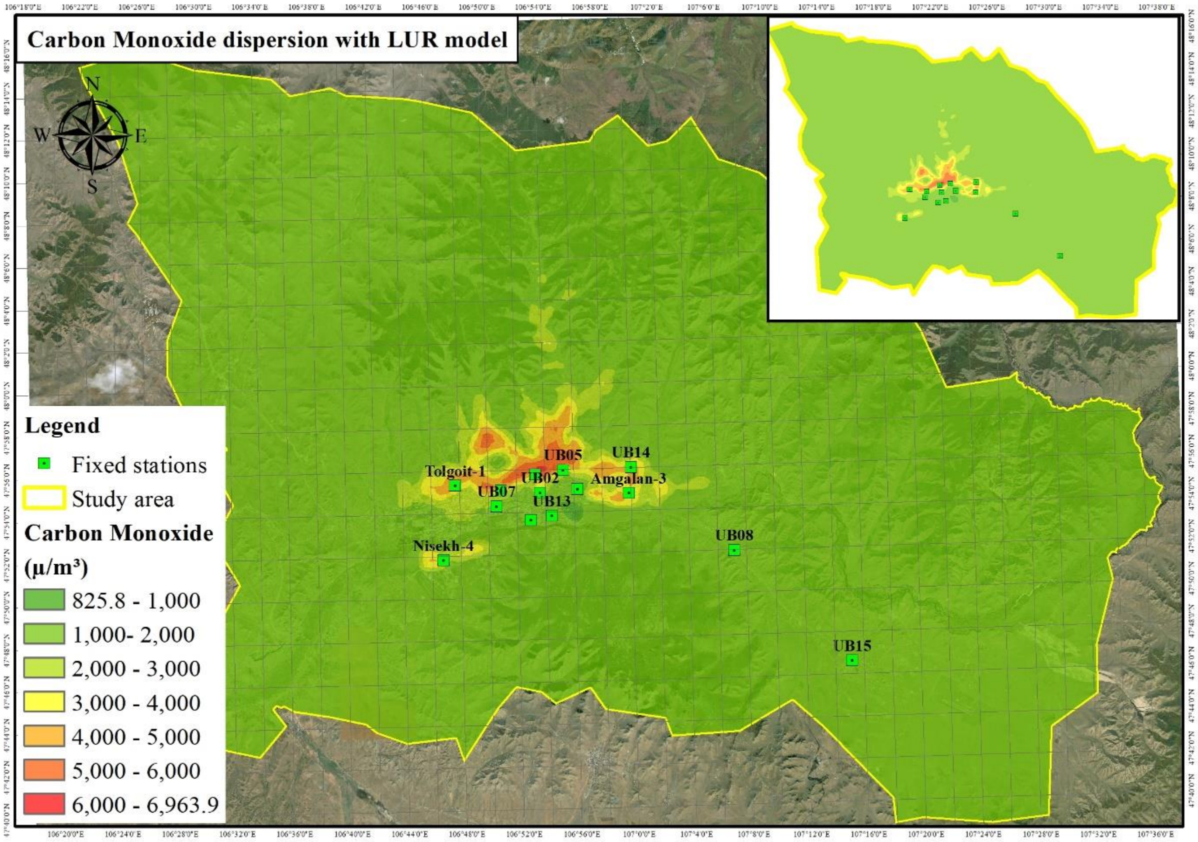

Figure 2. Sentinel 5P Tropomi and LUR model result maps

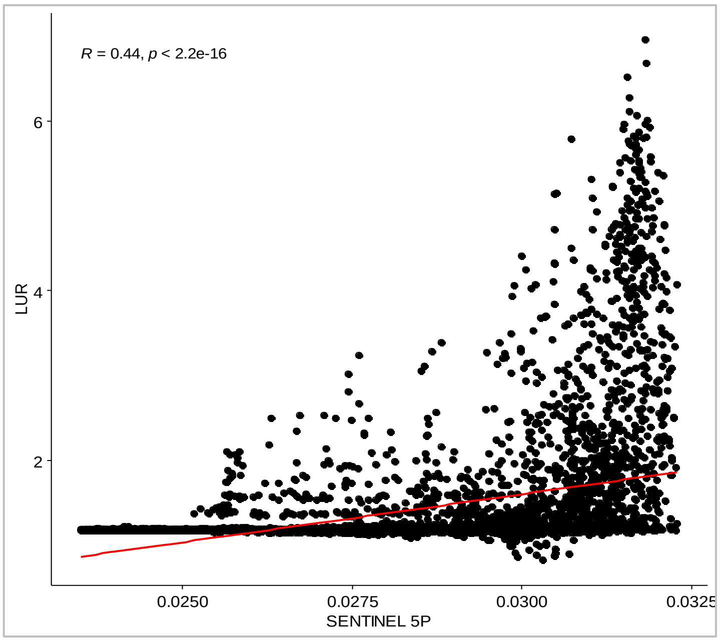

Figure 3. Correlation between Sentinel 5P data and LUR model result

Finally, performances of two result maps were compared with each other. To compare results, 15827 grid-points were created with 500m distance on these two maps and values were collected from Sentinel 5P and LUR model. Then all points values were correlated, which have shown "positively moderate correlation" or R=0.44

(Figure 3). As for mapping area, study area covers the entire territory of Ulaanbaatar because of remote sensing data coverage, and CO dispersion mainly dominated over residential areas. But, LUR model result covers only the central area of the city.

Evaluation of Sentinel 5P TROPOMI data and LUR model maps are showing relatively lower statistical-coefficients as compared with other similar studies [23] [24]. As for Sentinel 5P data, its spatial resolution is 5.5*7.5 km and even when we enhanced its resolution with some statistical techniques, it couldn't show a highly accurate map as it still had coarse spatial resolution, which is shown in Figure 2. Thus, this result correlated moderately with fixed station measurements and there is a need to improve the method to increase satellite data spatial resolution.

As for LUR model, only 14 station data (Figure 2) were used as independent variables in model and most of them are located in the city center. So, there is a lack of independent variables for LUR model, especially more stations are needed in the outskirt of the city that are able to represent characteristics of that environment. Using as many stations as possible perhaps can improve model performance. So, the authors have concluded that these lower coefficients are resulting in lower correlation.

In statistics, correlation refers to the fact that there is a link between various events. Especially, Pearson's correlation coefficient, which has been used in this study, is used for linearly related variables.Thus, 15827 grid-points have been created with 500m distance across the study area and these points got CO value from CO LUR model and TROPOMI CO dispersion map. After that, on each point two values were collected and correlated. As a result, Pearson's correlation coefficient is R=0.44 or positive moderate correlation, which means both image results move in the same direction. In other words, two result maps are showing almost the same results.

Finally, there are no CO air pollution distribution maps by other researchers for Ulaanbaatar city. Currently, researchers are mainly focused on particulate matter pollution, which originates from coal combustion. CO concentration in air over Ulaanbaatar city is strongly correlated with particulate matter pollution levels and so researchers have adopted the LUR model from particulate matter distribution study. The result of this model shows approximate distribution with $PM_{2.5}$ LUR model, and on the other hand, it proves that CO LUR model is an useable model for CO pollution in Ulaanbaatar city.

CONCLUSIONS

From these results, CO calculation from Sentinel 5P TROPOMI data is moderately correlates with fixed-monitoring data and LUR model performance is relatively higher than Sentinel 5P TROPOMI data. Correlation between them is moderate or R=0.44

LUR model is imported from previous study for PM2.5 dispersion. As for CO dispersion, its evaluation coefficients are reasonably higher and therefore, it is possible to conclude that this LUR model is available to use at Ulaanbaatar city scale for CO dispersion. Hence the LUR model is convenient for air pollution originating from coal combustion in Ulaanbaatar.

As for TROPOPMI data, it is not very convenient to use for city scale, especially in Ulaanbaatar, because, its spatial resolution is too coarse, and even though researchers have tried to improve its resolution at city level, it is still not convenient for Ulaanbaatar city. But the authors believe that it can be used at the country level and we are planning to use this data for the country-wide CO dispersion study.

Finally, even though these two map results are not exactly the same, Pearson's correlation coefficient shows that both image results move in the same direction or they are moderately showing the same results.

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REFERENCES

1. I. Ialongo, H. Virta, H. Eskes, J. Hovila, and J. Douros, “Comparison of TROPOMI/Sentinel-5 Precursor No 2 observations with ground-based measurements in Helsinki,” Atmospheric measurement techniques, Vol. 13, No. 1, pp. 205-2018, 2020. https://doi.org/10.5194/amt-13-205-2020
2. V. Safarianzengir, B. Sobhani, M. H. Yazdani, and M. Kianian “Monitoring, analysis and spatial and temporal zoning of air pollution (carbon monoxide) using Sentinel-5 satellite data for health management in Iran, located in the Middle East,” Springer: Air quality, Atmosphere and health, Vol. 13, pp. 709-719, 2020. https://doi.org/10.1007/s11869-020-00827-5.
3. A. Arfani, M. Dadang Basuki, and A. Wibowo, “Carbon Monoxide spatial pattern based on vehicle volume distribution in Tangerang city,” International Journal of Remote sensing and Earth sciences, Vol. 19, No. 1, 2022. https://doi.org/10.30536/j.ijreses.2022.v19.a3789.
4. World Health Organization, “WHO. Ambient (Outdoor) Air Pollution,” 12 December 2022. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health.
5. Mongolian Agency for Standard Metrology, “Air quality. General technical requirements,” Ulaanbaatar, 2007. [Online]. Available: https://old.estandard.gov.mn/standard/v/3377
6. D. Warburton *et al.*, “Impact of Seasonal Winter Air Pollution on Health across the Lifespan in Mongolia and Some Putative Solutions,” Annals of the American Thoracic Society, 2018. https://doi.org/10.1513/AnnalsATS.201710-758MG.
7. B. Jargalmaa, “Icon news,” 3 February 2019. [online]. Available: https://ikon.mn/n/1hus. [Accessed 5 May 2023].
8. National Agency for Meteorology and Environmental Monitroing, “Air pollution sources 2022,” Ulaanbaatar, [Online]. Available: http://www.agaar.mn/files/article/664/Agaariin%20bohirdliin%20tuhai%20tovchhon.pdf
9. O.Ekhjargal, B.Bumtsend and R.Tovuudorj, “Landform classification based on topographic position Index,” Mongolian Journal of Geography and Geoecology, Vol. 59, pp. 218–226, 2022. https://doi.org/10.5564/mjgg.v59i43.2530.
10. P. K. Davy, “Air particulate matter pollution in Ulaanbaatar, Mongolia: Determination of composition, source contributions and source locations,” Science direct: Atmospheric Pollution Research, Vol. 2, No. 2, pp. 126-137, 2011. https://doi.org/10.5094/APR.2011.017.
11. D. Amarsaikhan, V. Battsengel, B. Nergui et al, “A Study on Air Pollution in Ulaanbaatar City,” Journal of Geoscience and Environment Protection, Vol. 2, pp. 123-128, 2014. https://doi.org/10.4236/gep.2014.22017.

Vol. 64 No 01(249) 2024
DOI - https://doi.org/10.5564/pmas.v64i01.3545

12. S.K. Guttikunda, S.Lodoysamba, B.Bulgansaikhan, "Particulate pollution in Ulaanbaatar, Mongolia," Air Quality, Atmosphere & Health, Vol. 6, pp. 589-601, 2013. https://doi.org/10.1007/s11869-013-0198-7.

13. G.Ganbat, H. Lee, H-W Jo, B.Jadamba and D.Karthe "Assessment of COVID-19 Impacts on Air Quality in Ulaanbaatar, Mongolia, Based on Terrestrial and Sentinel-5P TROPOMI Data," Aerosol and Air Quality Research, Vol. 22, No. 10, 2022. https://doi.org/10.4209/aaqr.22019.6

14. World Bank, "Air Quality Analysis of Ulaanbaatar Improving air quality to reduce health impacts," World Bank, Washington, 2011. [Online]. Available: https://documents.worldbank.org/pt/publication/documents-reports/documentdetail/126141468288034414/main-report

15. O.Enkhjargal, M.Lamchin, J.Chambers and X-Y You, "Linear and Nonlinear Land Use Regression Approach for Modelling PM2.5 Concentration in Ulaanbaatar, Mongolia during Peak Hours," MDPI: Remote sensing, Vol. 15, pp. 1174, 2023. https://doi.org/10.3390/rs15051174.

16. European Space Agency, "Sentinel Online," European Union, [Online]. Available: https://sentinels.copernicus.eu/web/sentinel/data-products/-/asset_publisher/fp37fc19FN8F/content/sentinel-5-precursor-level-2-carbon-monoxide.

17. A.Vellalassery et al, "Using Tropospheric Monitoring Instrument (TROPOMI) measurements and Weather Research and Forecasting (WRF) CO modelling to understand the contribution of meteorology and emissions to an extreme air pollution event in India," Atmospheric Chemistry and Physics, Vol. 21, 2021. https://doi.org/10.5194/acp-21-5393-2021.

18. G.Kaplan and Z. YiGiT Avdan "Space-borne air pollution observation from Sentinel-5p Tropomi: relationship between pollutants, geographical and demographic data," International Journal of Engineering and Geosciences, Vol. 5, 2020. https://doi.org/10.26833/ijeg.644089.

19. National Agency for Meteorology and Environmental Monitoring, "Fixed stations data," Ulaanbaatar city, 2023.

20. H.J. Jumaah, M. H. Ameen and B.Kalantar et al., "Air quality index prediction using IDW geostatistical technique and OLS-based GIS technique in Kuala Lumpur, Malaysia," Geomatics, Natural Hazards and Risk, Vol. 10, 2019. https://doi.org/10.1080/19475705.2019.1683084.

21. C. Xu, J. Wang, M. Hu, and W. Wang "A new method for interpolation of missing air quality data at monitor stations," Elsevier: Environment International, Vol. 169, 2022. https://doi.org/10.1016/j.envint.2022.107538.

22. Europian Union, "Sentinel Hub," [online]. Available: https://apps.sentinel-hub.com/eo-browser/?zoom=6&lat=33.5&lng=41.24&themeId=Default-Theme. [Accessed 30 May 2023].

23. T. Borsdorff, J. Aan de Brugh , H.Hu, I.Aben, O. Hasekamp, and J. Landgraf, "Measuring Carbon Monoxide With Tropomi: First Results and a Comparison With ECMWF-IFS Analysis Data," Geophysical Letters, Vol. 45, pp. 2826-2832, 2018. https://doi.org/10.1002/2018GL077045.

24. G. Kaplan, Z.Y. Avdan, "Space-borne air pollution observation from Sentinel-5p TROPOMI: relationship between pollutants, geographical and demographic data," International Journal of Engineering and Geosciences, Vol. 5, pp. 130-137, 2020. https://doi.org/10.26833/ijeg.644089