SPATIAL VARIATION OF NO_2 LEVELS DURING THE COVID-19 PANDEMIC IN THE BALI TOURISM AREA

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DOI: 10.21163/GT_2022.171.11

ABSTRACT:
NO_2 levels that exceed quality standards will negatively impact the environment and human health. The purpose of this study was to determine changes in the content of NO_2 temporally. The method used is descriptive quantitative, with data analysis using Geographic Information Systems (GIS) and remote sensing data extraction using Google Earth Engine (GEE). The remote sensing data used is Sentinel 5p – TROPOMI whose sensors have the ability to detect air pollution. The results of this study indicate the occurrence of different variations during the Covid-19 Pandemic in the Bali Tourism Area, decreasing or increasing NO_2 levels. The decrease in NO_2 levels in the air is due to reduced human activities outside the home due to the implementation of the Indonesian Government's policies in the form of Large-Scale Restrictions, Work From Home (WFH), and the religious traditions of Hindus in Bali (*Nyepi* Day on March 25, 2020). NO_2 levels increase again after a long holiday in Indonesia on November-December 2020, due to the large number of tourists visiting Bali Province. The arrival of these tourists increases human activities around the tourism area, such as opening hotels, restaurants, and means of land, sea, and air transportation. Tourism areas tend to have high building density and population. Thus, making green open space low. Whereas green open space is very useful in absorbing air pollution, it is recommended to add green open space or revegetation in every hotel building to maintain good air quality.

Key-words: *Covid-19, Tourism, NO_2, Google Earth Engine, Bali.*

1. INTRODUCTION

Bali is known as a world tourist destination with an increasing number of tourists. From 2007 to 2019, the number of tourists increased by an average of 11.86%. The number of tourists in 2020 experienced a very drastic decline, namely by 82.96% (BPS Province of Bali, 2020). The decline in the number of tourists was due to the Covid-19 virus outbreak which paralyzed the Bali tourism sector, even the tourism sector throughout the world. The impact of Covid-19 has caused most tourism infrastructure businesses to close since early April 2020 and the layoff of employees in the tourism sector has increased (Nurudin et al., 2020).

The World Health Organization (WHO) has announced that Covid-19 is a world pandemic resulting in a lockdown for several countries including Italy, China, the UK, and other countries. Indonesia does not implement Lockdown but rather a Large-Scale Social restriction (PSBB) and Work From Home (WFH). The implementation of PSBB is carried out in the Covid-19 red zone areas, one of which is Jakarta. The implementation of WFH is implemented in all regions in Indonesia, one of which is the Province of Bali. The implementation of these two policies reduces human activities outside the home so that it is hoped that it will be able to suppress cases of Covid-19 transmission. The Covid-19 outbreak in addition to having a detrimental impact also has a positive impact, namely reducing air pollution. This is due to the decreasing number of human activities in tourism and other activities. One of the activities that cause air pollution is a motorized vehicle which is an accommodation in human activities. As much as 70% of air pollution is caused by transportation activities (Arifin and Sukoco, 2009). Budiyanto (2011) states that motor vehicle fumes make a major contribution to air quality pollution.

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Gorglulu (2018) stated that air pollution contains corrosive exhaust gases, namely NO_x. NO_x gas contains 2 gases, namely nitrogen monoxide (NO) and nitrogen dioxide (NO_2). The transportation sector accounts for pollutant NO_2 by 69% in urban areas, followed by industry and households (Mukono A, 2006). The level of NO_2 in the air if it is too high above the Air Pollution Standard Index (ISPU) 100 will have a negative impact on human health (Prayudi et al, 2010).

Actually, given the current digital advance, the NO2 data can be obtained via satellite, known also as the remote sensing data. The satellite that plays a role in monitoring air quality is Sentinel 5-P. Sentinel 5-P has a mission to monitor air quality, climate, and the ozone layer on a global scale from 2017 to 2023, thereby providing better data to support research on NO_2 (Berger et al, 2012). As the first imaging spectrometer to provide global data at the moderate spatial resolution, TROPOMI has significant advantages over previous sensors in resolution (7 x 3.5 km) and the number of observations with low cloud cover (Guanter et al, 2015). The use of remote sensing data, derived from Sentinel-5P since the Covid-19 incident, for air quality monitoring, is often carried out by researchers around the world. The NO_2 species originating from Sentinel-5P, has not been widely studied in Indonesia, especially Bali Province during the Covid-19 pandemic, so that is the reason for researchers to explore monthly NO_2 satellite data during 2020.

2. STUDY AREA

The research was conducted in Bali Province (**Fig.1**) from January to December 2020. The province of Bali consists of 8 regencies (Badung, Tabanan, Jembarana, Buleleng, Karangasem, Bangli, Gianyar, Klungkung) and 1 City (Denpasar). The province of Bali is geographically located between 360000 mE and 910000 mN to 220000 mE and 9020000 mN. Each district and city has a tourist attraction and tourism infrastructure, but tourism sector activities are more dominant in the coastal part of Bali due to the natural potential, namely beach panoramas.

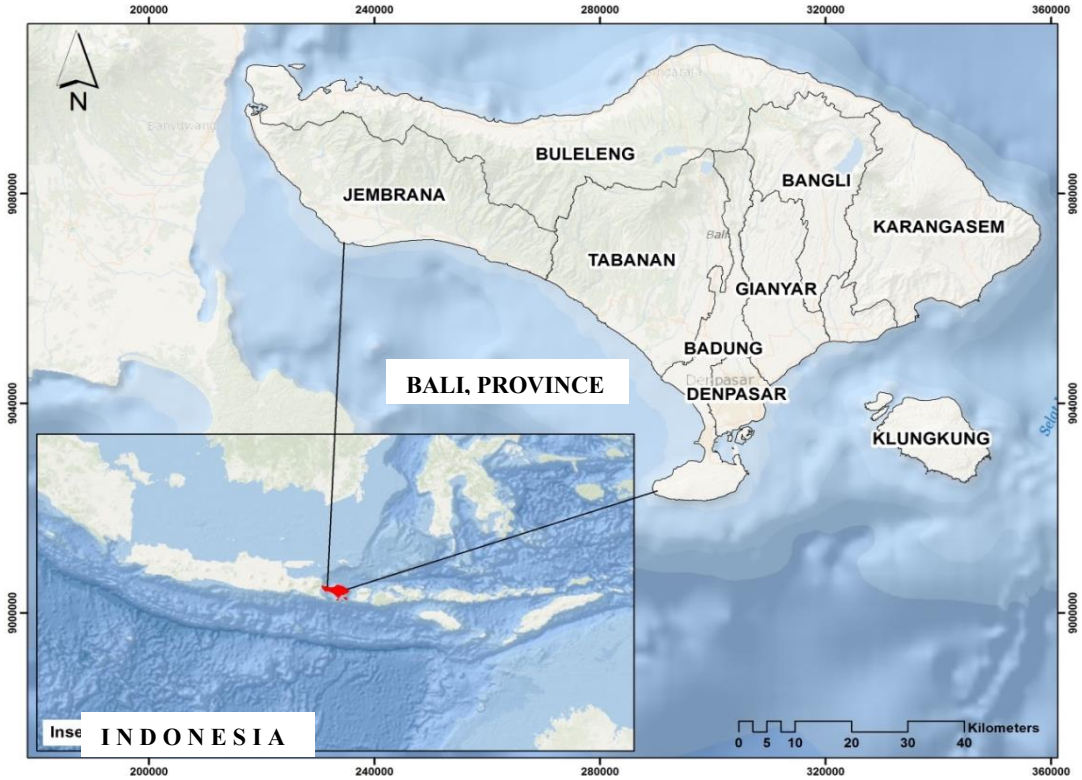

Fig. 1. Research Locations in Bali Province-Indonesia (Located on the World Geodetic System Projection (WGS) 1984 - Universal Transverse Mercator (UTM) 50 South Zone.

3. DATA AND METHODS

3.1. Remote Sensing Data

The main tool that will be used in this research is Google Earth Engine (GEE). Google Earth GEE is a platform cloud-based spatial data computing developed by Google, which offers a worldwide analysis of environmental data. GEE is used to analyze satellite data to produce the distribution of pollutant concentrations. GIS software (ArcGIS 10.6) is used to process spatial data and map layout.

The processed data is TROPOspheric Monitoring Instrument (TROPOMI) data brought by the Copernicus Sentinel-5 Precursor satellite. The instrument, the single payload of the Sentinel-5P spacecraft, uses passive remote sensing techniques to achieve its goal by measuring, at the Top Of Atmosphere (TOA), the solar radiation reflected and emitted from the earth. The instrument operates in a push sweep (non-scan) configuration, with a sweep width of ~2600 km at the earth's surface. The primary objective of the Copernicus Sentinel-5P mission is to perform atmospheric measurements with high spatio-temporal resolution, which will be used for air quality, ozone, UV radiation, and climate monitoring & forecasting. The satellite was successfully launched on October 13, 2017, from the Plesetsk cosmodrome in Russia. The TROPOMI instrument combines the power of SCIAMACHY, OMI, and advanced technology to provide observations with performances that today's instruments cannot meet in space. The performance of current orbital instruments is surpassed in terms of sensitivity, spectral resolution, spatial resolution, and temporal resolution (European Space Agency, 2014). The Nitrogen Dioxide data was released on 10 July 2018 and is accessible on the GEE platform. NO_2 in GEE has a spatial resolution of 0.01° or 1.11 km per pixel. In this study, Sentinel-5P satellite data was used to monitor changes in NO_2 pollutants during the Covid-19 pandemic in Bali Province. The variable of this research is the level of NO_2 extracted from the Sentinel 5-P Satellite Remote Sensing Data by cloud computing through the GEE platform. Utilization of Sentinel 5-P satellite data for air quality monitoring has been carried out by (Zheng et al, 2019; Lorente et al, 2019; Mahato et al, 2020; Otmani et al, 2020; Shikwambana et al, 2020; Goldberg et al, 2020; Sanningrahi et al, 2021) in several countries, including China, India, Paris, and Africa. NO_2 monitoring has also been previously studied by (Rushayati et al, 2020) in the Greater Jakarta Region of Indonesia.

3.2 Data Analysis

Sentinel 5P TROPOMI satellite data is available in high temporal resolution (daily). Therefore, it is necessary to filter by data acquisition date. The date range chosen is January 2020 to December 2020. The time range was chosen to determine changes in NO_2 gas concentration before WFH was implemented when WFH was implemented, and after New Normal was implemented during the Covid-19 Pandemic in Bali Province. The result of this filtering process is a twelve-month temporal composite image for each pollutant gas NO_2. Each data is then clipped to get the area according to the focus area of the study, namely the Province of Bali. This process is carried out on the GEE platform. The resulting data is then exported for later download so that it can be opened in GIS software (ArcGIS 10.4). Furthermore, the results of data extraction for each pixel are compared both spatially and temporally from January 2020 to December 2020. To get the trend of changes in NO_2 levels for each district, an overlay is carried out on the district boundaries in Bali Province.

4. RESULTS AND DISCUSSIONS

4.1. Data Analysis on GEE

Data analysis in GEE uses the programming language JavaScript. Data analysis was carried out by importing Sentinel-5P NRTI NO_2 data: Near Real-Time Nitrogen Dioxide. Next, filter date and average NO_2 data for each month during 2020 and carried out masking is image based on research boundaries so that levels are obtained for the Province of Bali. **Fig. 2** is a visualization of the dashboard GEE. The utilization of GEE for data analysis makes it easy for users including a fast process, does not require high computer specifications, and saves computer memory because the data

analysis process is carried out with cloud computing by utilizing Google servers. It displays a dashboard GEE on the analysis of NO_2 levels during 2020.

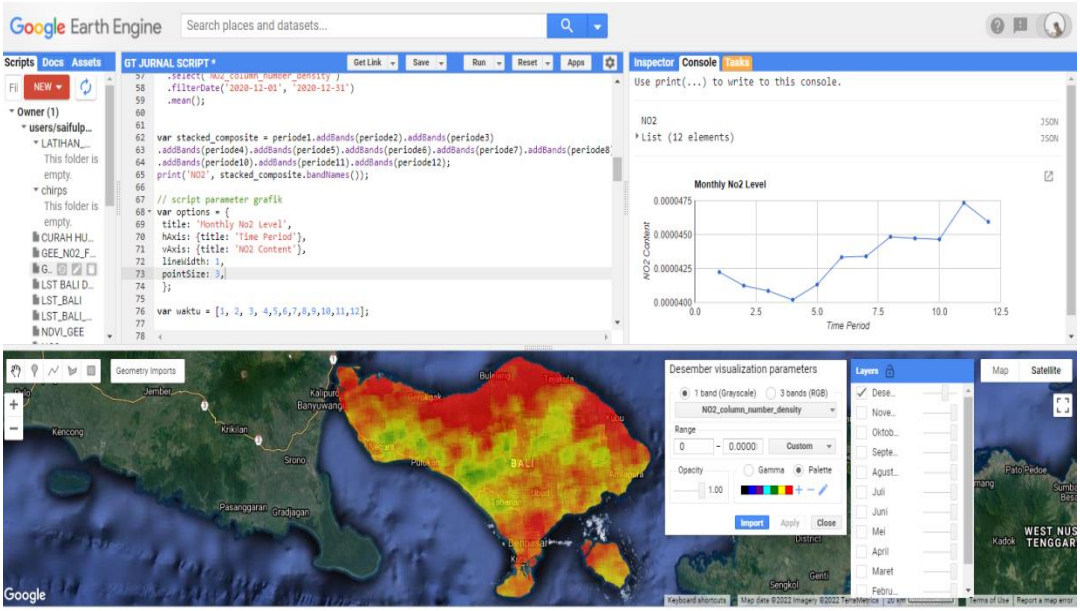

Fig. 2. Google Earth Engine Dashboard: Data Analysis by cloud computing platform.

4.2. Spatial Distribution of NO_2 Levels

The results of NO_2 data extraction show different levels of levels during 2020 due to the Covid-19 pandemic (**Fig. 3**). In January and February, the Government has not implemented the WFH policy, because the Covid-19 outbreak has not yet entered Indonesian territory. The condition of NO_2 levels was still relatively high but continued to decline until April 2020. The decrease in NO_2 levels was due to the WFH policy during March-June 2020. The Decrease in NO_2 lowest levels occurred in March and April 2020. Such conditions because on March 11, 2020, WHO has announced that Covid-19 is a world pandemic so that tourism activities and other activities are limited. March 25, 2020, is *Nyepi* Day for Hindus in Bali, so there is no human activity outside the house for 24 hours. In July, the Bali Provincial Government announced the Policy New Normal and the opening of several tourist attractions, causing human activities to begin to increase. The increase in NO_2 levels also occurred in Java (Zulkarnain, 2020), (Anggraini, 2020) in line with the implementation of the New Normal and the easing of Large-Scale Social Restrictions (PSBB). The graph of NO_2 levels starting from July to peaking in November continues to experience an increase in NO_2 levels.

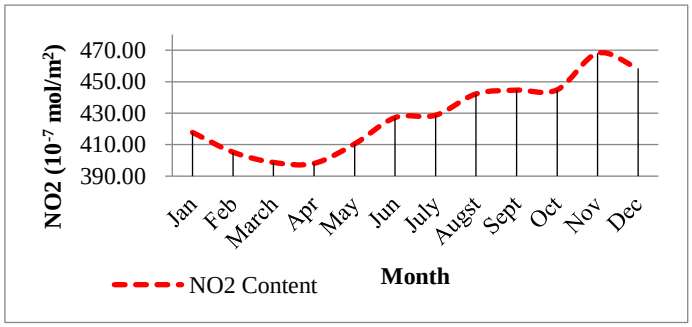

Fig. 3. Graph of Variability of NO_2 Levels During 2020: extraction from Sentinel 5P remote sensing data.

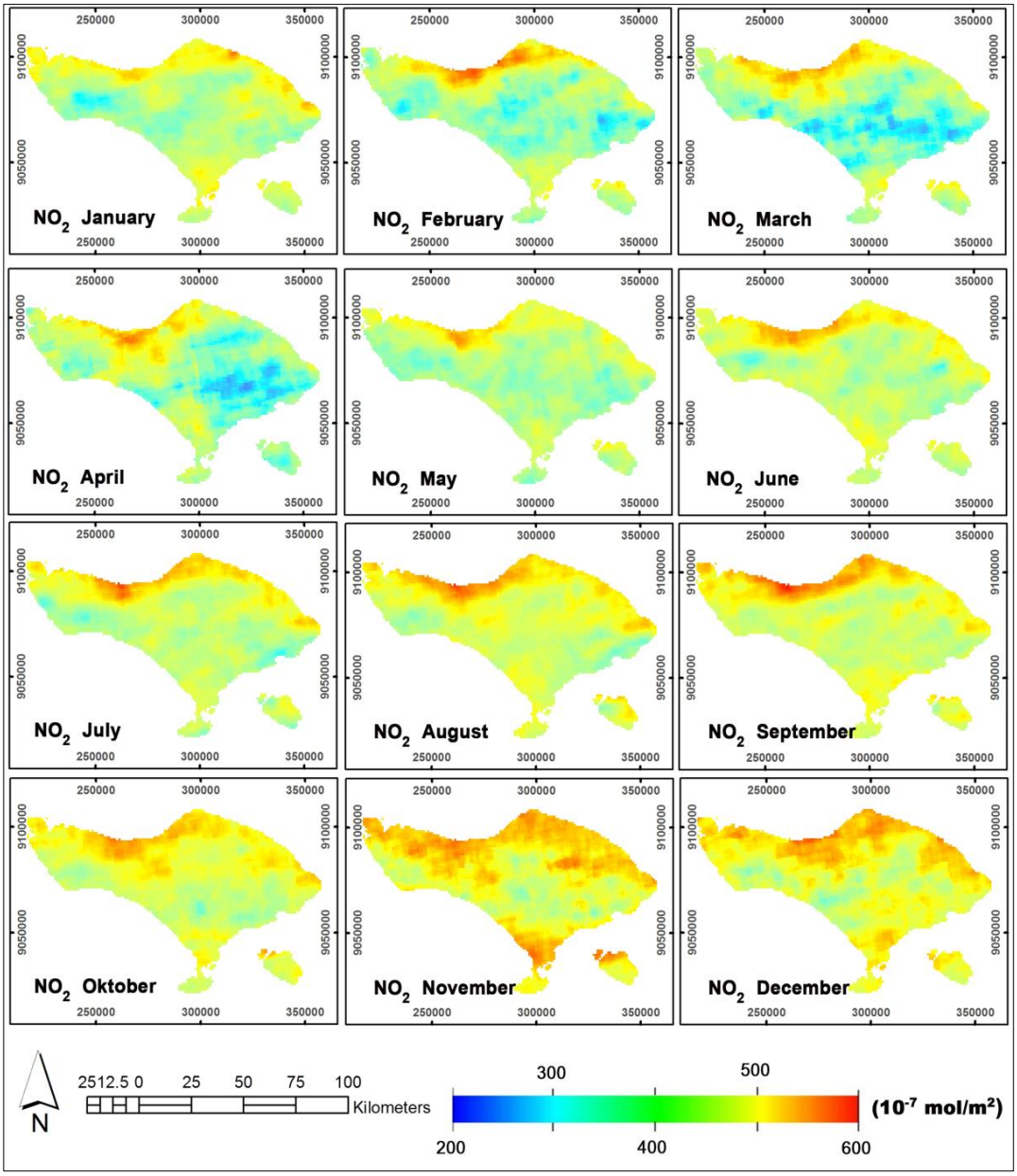

Fig. 4. Spatial Distribution of Monthly NO_2 Levels, During 2020.

Fig. 4 shows the spatial-temporal changes in NO_2 levels before the Work From Home (WFH) policy was implemented (January and February 2020), when WFH was applied (March-June 2020), after the WFH or New Normal policy (July-December 2020).

Prior to WFH, spatially on the map showed the dominance of light blue, green, yellow, and orange. When applied WFH spatially on a map showing variations of the new color dark blue and orange color with shrinking lead to a decline in levels of NO_2. Once set policy, the New Normal dark blue color on the map began to disappear and be replaced by orange, indicating increased levels of NO_2. Spatially kadaNO_2 highest are located throughout the coastal province of Bali, which is the center of tourism activities and other activities in the province of Bali.

4.3 NO_2 Level Per District

Table 1 shows the changes in NO_2 for each district in the province of Bali. The average levels of NO_2 were 425.32 10^{-7} mol/m^2 were found to be evenly distributed throughout the County and City in the province of Bali. Levels of NO_2 low of 344.74 10^{-7} mol/m^2 contained in April in Gianyar Regency. The highest levels of NO_2 reaches 512.62 10-7 mol/m^2 contained in November in the city of Denpasar. **Fig. 5** shows changes in NO_2 levels in each District in Bali Province in 2020. The pattern of increase and decrease in the graph is relatively the same for each Regency, except for Buleleng Regency which shows NO_2 levels higher than January-December 2020. This is presumably due to the existence of tourism activities in the coastal part of the Buleleng Regency and the influence of land transportation on the Mengwitani-Singaraja route.

Table 1.

NO_2 Levels of Each Regency in Bali Province in 2020.

	Average Nitrogen Dioxide Level (10^{-7} mol/m^2) in 2020											
Regency	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Okt**	**Nov**	**Dec**
Badung	416.56	394.10	378.12	395.29	399.95	420.25	419.88	435.41	434.60	428.03	459.86	454.34
Bangli	418.27	399.70	379.30	355.52	409.08	419.49	424.17	437.67	434.92	442.12	481.74	443.69
Buleleng	441.91	453.57	455.92	449.02	441.24	454.01	462.80	476.92	478.10	477.10	494.04	494.68
Denpasar	455.52	435.91	433.22	412.18	427.60	439.23	425.33	433.30	450.90	447.83	512.62	475.33
Gianyar	414.51	393.30	361.79	344.74	402.92	415.38	416.67	421.26	432.64	425.30	441.41	451.93
Jembrana	392.41	390.31	396.93	406.58	392.20	417.53	409.79	425.17	439.70	433.31	459.94	439.47
Karangasem	424.30	383.72	374.16	365.74	403.55	421.46	424.27	435.59	434.10	441.39	461.92	463.73
Klungkung	415.33	406.58	398.79	373.71	407.46	414.25	412.35	427.65	437.81	431.14	465.25	454.12
Tabanan	393.71	372.59	365.80	398.85	393.87	415.58	416.81	432.29	423.67	432.08	441.13	427.28

Source : Sentinel 5P remote sensing data.

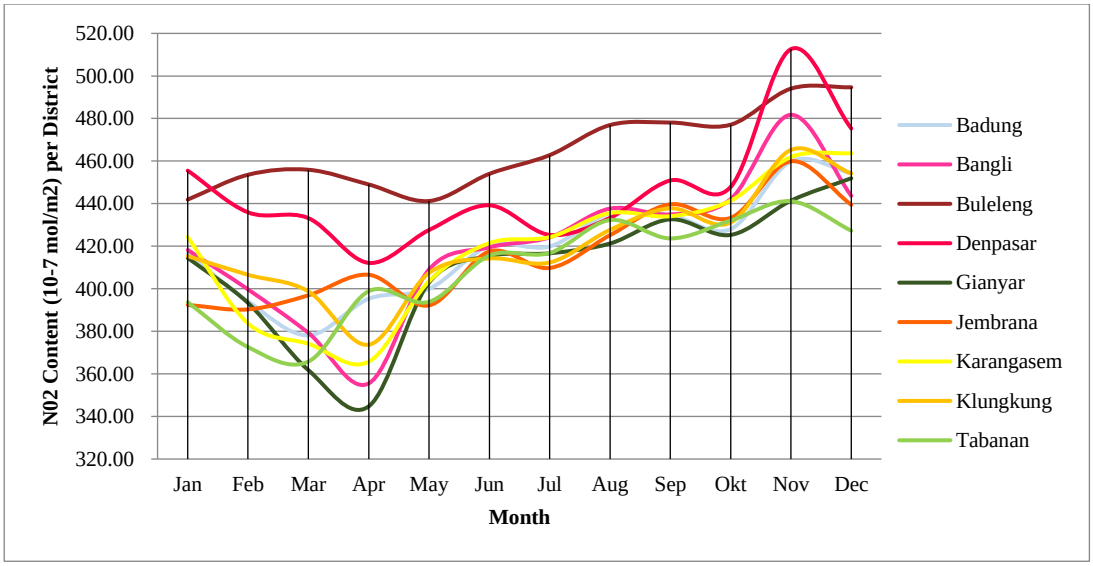

Fig. 5. Graph of Changes in NO_2 Levels for Each District in Bali Province in 2020.

5. DISCUSSION

Google Earth Engine is an a-based cloud platform that can be used for regional, national and global environmental data analysis. The utilization of GEE for global-scale remote sensing data analysis has been carried out by Tamiminia, 2020 while utilization on a regional scale is one of them for the identification of land cover (Novianti, 2020) and land cover changes (Wang, 2020). Earth Engine consists of catalog data used for computationally based analysis with a fast and integrated process. Earth Engine also offers an Integrated Development Environment (IDE) online for the visualization of complex spatial data using Javascript API (Gorelick, 2017). The use of GEE in this study was implemented in the calculation of the 2020 Monthly NO_2 levels in the Province of Bali. The results of this study indicate that the highest variability of NO_2 levels is in the Tourism Area.

Territorial tourism destinations include tourism areas (KP) and special tourist attraction areas (KDTWK) It has been regulated in Regional Regulation No. 3 of 2020. Pujaastawa (2016) states that tourism areas are strategic tourism areas that are the ones that are geographically located in one or more village administrative areas that have the potential for tourist attraction, accessibility, tourism facilities, and social and cultural activities of the community that support each other. The Special Tourist Attraction Area (KDTWK) is a strategic tourism area located in the geography of one or more administrative areas of 4 villages that have the potential for tourist attraction, accessibility, and limited tourism facilities as well as community social and cultural activities that support each other, but its development very limited to be more directed to the preservation of culture and the environment.

On average, tourism areas in Bali Province are spatially located along the coast of Bali Province. The tourism area in Bali Province has relatively high human activities. Because in this area there are tourist destinations, dense settlements and tourism facilities (hotels, restaurants, mini markets, etc.). The area is the center of the economy and the center of human activities in Bali Province so that the pollutants in the form of NO_2 levels as a result of these activities are high before the WFH policy is implemented and after the WFH/New Normal policy is implemented. However, the levels of NO_2 decreased with the ongoing implementation of the WFH due to the decline of human activities in the area of Bali Provincial Tourism.

Fig. 6 shows the relationship between tourism areas and NO_2 levels. A high level of NO_2 is shown with a dark orange color. **Fig. 6** is the average level of NO_2 in the Sentinel 5-P image acquisition from January 1 to November 30, 2020. The data was chosen because it shows NO_2 levels a drastic increase compared to the previous month during 2020. Spatially, almost all tourism areas have high levels of NO_2 in November 2020. Accessibility such as Seririt‑Singaraja Roads, Singaraja-Gilimanuk in the northern coastal area of Bali Province as well as, Gatot Subroto Roads, By Pass Ngurah Rai Roads, and Imam Bonjol Roads, Denpasar City are contributors to high levels of NO_2 because of the use of various land transportation. Arifin (2009) and Budianto (2011) stated that air pollution (NO_2), the biggest cause is due to motorized vehicle activity on the highway. Febriani (2021) also suggested a reduction in the use of modes of transport and industrial activity during Large-Scale Social Restriction (PSBB) and WFH can degrade air quality NO_2.

The high level of NO_2 in Bali Province spatially occurs in the center of the tourism industry. The center of the tourism industry is dominated by built-up land so it has low vegetation cover. The low area of green open space and low vegetated land cover are the causes of high levels of NO2 (Rusyayati, 2020). So it is necessary to add green space, which functions as an absorber of harmful NO_2 levels in the air (Purwanto, 2021).

NO_2 levels during the Covid-19 pandemic show different variations in values. This study found that human activities have an effect on these variations. The *Nyepi* Day for Hindus in Bali, as well as the government's policy to limit activities outside the home, have caused NO_2 levels to decrease, and air quality to improve. This condition only occurred during March 2020. Other studies also stated that due to restrictions on human activities outside the home, NO_2 levels decreased (Copat et al., 2020; Berman & Ebisu, 2020; Chu et al., 2021; Paital et al., 2021). The weakness of this study is related to the short duration of time, so it cannot distinguish variations in NO_2 before the COVID-19 pandemic (before 2020) and when Covid-19 occurs (starting in 2020).

Because other studies stated that there was an increase in NO_2 concentrations before the Covid-19 pandemic, including in urban area of Klang Valley, Malaysia and Bangkok Metropolitan Thailand (Nadzir et al., 2020; Wetchayont et al., 2021.

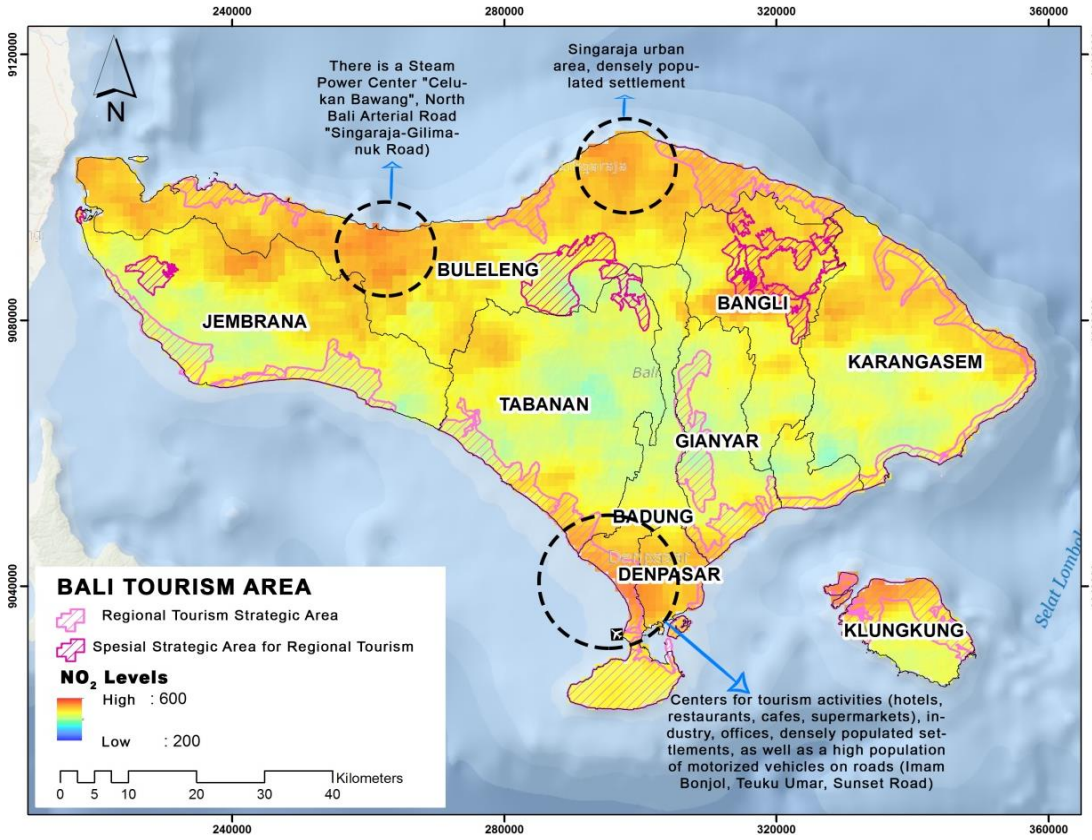

Fig. 6. Map Overlay: Tourism Areas with NO_2 Levels During 2020.
Source: Tourist Area Map from Bali Province Spatial Plan 2009-2029.

6. CONCLUSIONS

Air pollution is known as an environmental problem associated with urban areas around the world. Air pollution is also an indicator of environmental quality that has an impact on public health and affects air quality in the region. Modern era, in line with the development of the physical development of cities and industrial centers, as well as the development of transportation, the air quality also undergoes changes due to air pollution. NO_2 emissions are affected by population density because the main source of NO, which is produced by humans is from combustion and most of the combustion is caused by vehicles, energy production, and waste disposal. The Covid-19 outbreak that has hit the world has caused enormous losses to the tourism sector in Bali Province. But on the other hand, it provides benefits for environmental recovery, which is shown by decreasing NO_2 levels in the air. The decrease in NO_2 levels in the air is due to reduced human activities outside the home due to the implementation of the Indonesian Government's policies in the form of Large-Scale Restrictions, Work From Home (WFH), and the religious traditions of Hindus in Bali (Silent/ Nyepi Day). Nyepi Day makes people in Bali, lock themselves and meditate at home for 24 hours, without any activity on March 25, 2020. Even though the Covid-19 pandemic is still ongoing, it turns out that NO_2 levels are back up after a long holiday in Indonesia on November-December 2020, due to the large number of tourists visiting Bali Province.

The arrival of these tourists increases human activities around the tourism area, such as opening hotels, restaurants, and means of land, sea, and air transportation. Tourism areas tend to have high building density and population. Thus, making green open space low. Whereas green open space is very useful in absorbing air pollution, it is recommended to add green open space or revegetation in every hotel building to maintain good air quality.

REFERENCES

Anggraini, T. S., Artaningh, F., Sihotang, E., Sakti, A., & Agustan, A. (2020). Variations in Nitrogen Dioxide Emissions during Large-Scale Social Restrictions in West Java Province from Sentinel-5p Data Processing. Indonesian Journal of Remote Sensing, 2(2), 19-24. Retrieved from http://jurnal.mapin.or.id/index.php/jpji/article/view/34

Arifin, Z.M.T, & Sukoco. (2009). Vehicle Pollution Control. Bandung: Alfabeta

Berger, M ; Moreno, J ; Johannessen, J.A ; Levelt, P F ; Hanssen, R F. 2012. ESA′s sentinel missions in support of Earth system science. Remote Sens. Environ. 120, 84‑90. 37.

Berman, J. D., & Ebisu, K. (2020). Changes in US air pollution during the COVID-19 pandemic. Science of the total environment, 739, 139864.

Chu, B., Zhang, S., Liu, J., Ma, Q., & He, H. (2021). Significant concurrent decrease in PM2. 5 and NO2 concentrations in China during COVID-19 epidemic. Journal of Environmental Sciences, 99, 346-353.

Copat, C., Cristaldi, A., Fiore, M., Grasso, A., Zuccarello, P., Santo Signorelli, S., ... & Ferrante, M. (2020). The role of air pollution (PM and NO2) in COVID-19 spread and lethality: a systematic review. Environmental research, 191, 110129.

Febriani, RA (2021) The Effect of the Number of Transportation Modes and Industrial Closures on Air Quality at PSBB During the Covid-19 Pandemic In DKI Jakarta Province. Undergraduate Thesis, Diponegoro University.

Goldberg, D.L., Anenberg, S.C., Griffin, D., McLinden, C.A., Lu, Z., Streets, D.G., 2020. Disentangling the impact of the COVID-19 lockdowns on urban NO_2 from natural variability. Geophys. Res. Lett. 47 (17), e2020GL089269.

Gorelick N, Hancher M, Dixon M, lyushchenko S, Thau D, Moore R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. 202, 18-27. https://doi.org/10.1016/j. rse.2017.06.031

Guanter, L ; Aben, I ; Tol, P ; Krijger, J.M ; Hollstein, A ; Köhler, P ; Damm, A.; Joiner, J.; Frankenberg, C.; Landgraf, J. (2015). Potential of the TROPOspheric Monitoring Instrument (TROPOMI) onboard the Sentinel-5 Precursor for the monitoring of terrestrial chlorophyll fluorescence. Atmos. Meas. Tech. 8, 1337‑1352.

Lorente, A., Boersma, K.F., Eskes, H.J., Veefkind, J.P., van Geffen, J.H.G.M., de Zeeuw, M.B., Denier van der Gon, H.A.C., Beirle, S., Krol, M.C., (2019). Quantification of nitrogen oxides emissions from build-up of pollution over Paris with TROPOMI. Sci. Rep. 9, 20033. https://doi.org/10.1038/s41598-019-56428-5.

Mahato, S., Pal, S., Ghosh, K.G., (2020). Effect of lockdown amid COVID-19 pandemic on air quality of the megacity Delhi, India. Sci. Total Environ. 730, 139086. https://doi. org/10.1016/j.scitotenv.2020.139086.

Mukono, H.J. (2006). Air Pollution and Its Effect on Respiratory Tract Disorders. Surabaya: Airlangga University Press.

Nadzir, M. S. M., Ooi, M. C. G., Alhasa, K. M., Bakar, M. A. A., Mohtar, A. A. A., Nor, M. F. F. M., ... & Nor, M. Z. M. (2020). The impact of movement control order (MCO) during pandemic COVID-19 on local air quality in an urban area of Klang valley, Malaysia. Aerosol and Air Quality Research, 20(6), 1237-1248.

Novianti TC. (2021). Land Cover Classification Using Google Earth Engine. Jurnal Geografi dan Pembelajaran Geografi. Vol 6, No 1. DOI: http://dx.doi.org/10.31851/swarnabhumi .v6i1.5105.

Nuruddin, Wirawan PE, Pujiastuti S, Astuti, NNS. (2019). Hotel Survival Strategy in Bali During the Covid-19 Pandemic Journal of Bali Studies (Journal of Bali Studies), [S.l.], v. 10, n. 2, p. 579‑602, oct. 2020. ISSN 2580-0698. doi: https://doi.org/10.24843/JKB.2020.v10.i02.p11.

Otmani, A., Benchrif, A., Tahri, M., Bounakhla, M., Chakir, E.M., El Bouch, M., Krombi, M., (2020). Impact of covid-19 lockdown on PM10, SO2 and NO2 concentrations in sal ´ e city (Morocco). Sci. Total Environ. 735, 139541. https://doi. org/10.1016/j.scitotenv.2020.139541.

Paital, B., & Agrawal, P. K. (2021). Air pollution by NO2 and PM2. 5 explains COVID-19 infection severity by overexpression of angiotensin-converting enzyme 2 in respiratory cells: a review. Environmental Chemistry Letters, 19(1), 25-42.

Prayudi, T. dan J. P. Susanto. 2001. Dust Quality in Air as Impact of Flat Metal Casting Industry. Journal of Environmental Technology, Vol. 2, No. 2, Mei 2001: 168‑174.

Pujaastawa IBG. (2016). Development Model and Regional Tourism Problems in Bali. National Seminar and Workshop on Bali's Regional Tourism Policy in the Framework of Towards Equitable and Sustainable Tourism. Udayana University Culture and Tourism Research Center

Purwanto Utomo, H., & Ratnawati, R. (2021). Vegetation Effectiveness for Reducing Carbon Monoxide (CO) and Nitrogen Dioxide (NO2) levels. Time: UNIPA Engineering Journal, 19(01), 38-43. https://doi.org/10.36456/waktu.v19i01.3638

Putria DPD, Santosa B. (2021). Correlation Analysis of Nitrogen Dioxide Gas Variations on the Increase in Positive Cases Confirmed by Covid-19 Case Study of East Java Province. Geomatics Engineering Scientific Journal. IMAGI (2021) Vol. 1

Regional Regulation of Bali Province Number 3 of 2020 concerning Amendments to Regional Regulation Number 16 of 2009 concerning Spatial Planning of the Province of Bali for 2009-2029

Rusyayati SB, Hermawan R, Setiawan Y, Wijayanto AK, Prasetyo LB, Permatasari PA. (2020). The effect of the pattern of utilization of green open space on the dynamics of changes in air quality due to the Covid-19 Pandemic in the Greater Jakarta Area. Journal of Natural Resources and Environmental Management. 10, 559-567. http://dx.doi.org/10.29244/jpsl.10.4.559-567

Sanningrahi S., Kumar P., Molter A., Zhang Q., Basu B., Basu AS., Pilla F., (2021). Examining the status of improved air quality in world cities due to COVID-19 led temporary reduction in anthropogenic emissions. Environmental Research. 196, 1-22. https://doi.org/10.1016/j. envres.2021.110927

Shikwambana, L., Mhangara, P., Mbatha, N., (2020). Trend analysis and first time observations of sulphur dioxide and nitrogen dioxide in South Africa using TROPOMI/Sentinel-5 P data. Int. J. Appl. Earth Obs. Geoinf. 91, 102130. https:// doi.org/10.1016/j.jag.2020.102130.

Tamiminia, H., Salehi, B., Mahdianpari, M., Quackenbush, L., Adeli, S., Brisco, B., (2020). Google Earth Engine for geo-big data applications: A meta-analysis and systematic review. ISPRS Journal of Photogrammetry and Remote Sensing, 164, 152‑170. https://doi.org/10.1016/j.isprsjprs.2020.04.00 1

The European Space Agency. (2014). User Guide Sentinel 5 P. https://sentinels.copernicus.eu/ web/sentinel/user-guides/sentinel-5p-tropomi. Diakses pada 1 April 2021.

Wang, L., Diao, C., Xian, G., Yin, D., Lu, Y., Zou, S., Erickson, T. A. 2020., A summary of the special issue on remote sensing of land change science with Google earth engine. Remote Sensing of Environment, 248 . https://doi.org/10.1016/j.rse.2020.112002

Wetchayont, P., Hayasaka, T., & Khatri, P. (2021). Air quality improvement during COVID-19 lockdown in Bangkok metropolitan, Thailand: Effect of the long-range transport of air pollutants. Aerosol and Air Quality Research, 21, 200662-200662.

Zheng, Z., Yang, Z., Wu, Z., Marinello, F., (2019). Spatial variation of NO2 and its impact factors in China: an application of sentinel-5P products. MDPI Remote Sensing . 11, 1‑24. https://doi.org/ 10.3390/rs11161939.

Zulkarnain R. Ramadani KD. (2020). Kualitas Udara dan Potensi Transmisi COVID-19 di Pulau Jawa. Conference: Seminar Nasional Official Statistics 2020.