Developing data approaches for accumulation of plastic waste modelling using environment and socio-economic data product

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Abstract. Today the world faces the fact that 10 million tonnes of waste, primarily plastic waste, pass through the river. This global issue has become a serious problem that can be resolved with location-based that utilizes remote sensing technology, following recent developments of technology. This study aims to estimate the weight of potential plastic waste at the estuary before it enters the ocean and becomes marine debris. Several parameters are developed based on three main aspects, which are environment as graded by LULC, social aspect as provided by population density using building data, and economic aspect as provided by nightlight from NOAA’s VIIRS. The estimation used raster-based digital numbers processing, by using estimated data and providing weight. As a result, it shows that most of the metropolitan cities such as Jakarta contribute almost 507 tonne of plastic waste per day. For other cities, its generation is directly proportional to the increase in population. This study could become a consideration to synthesize policies, with the fact that massive population density impacts the increasing of the plastic waste generation.

1. Introduction
Plastic waste consumption and production have been increasing in the mainland's activity throughout the past decades. Established in 1970, plastic waste was founded floating on the ocean [1], which indicated mismanaged and unmanaged plastic from the continents. Along with plastic materials, which are characterized as durable and useful, humans keep producing more of these materials. Plastic waste is commonly produced by land activity, where the intensive activity of humans is the main problem [2]. An estimated 80 to 90% of the plastic waste that enters the ocean comes from activities from the land ecosystem [3]. Consequently, the massive yet irresponsible production of plastic results in grand impacts. Other studies have proven that unmanaged plastic waste could threaten and endanger us, in which unmanaged plastic waste has threatened the marine life of 700 species [4].

As mentioned before, plastic waste first polluted the ocean in around 1997, which was followed by 6.4 million tonnes in the following 5 years [1]. Integration among continents and ocean provided coastal
areas and an estimated global average of 1.51 to 2.4 million tonnes of waste annually [5]. Additionally, a study of coastal countries in 2015 showed that Indonesia placed 2nd on mismanaged plastic waste input through the ocean by 0.48 to 1.29 MMT per year [1]. Research observing the dataset of rivers around the world also shows that from the most 20 rivers polluted, four rivers in Indonesia (i.e. Brantas, Solo, Serayu, Progo) were included on the list, with the highest estimation of approximately 6.37 x 104 tonne per year (Brantas River, claimed to be the most polluted river in Indonesia) [5]. Apparently, in 2018, Cartographer Riccardo Pravettoni compared and showed produced and mismanaged plastic waste, in which Indonesia took the greatest ratio of mismanaged to produced plastic waste at 5:1 [6], which puts Indonesia on the red zone of plastic waste disposal.

Consequently, the global total amount of mismanaged plastic waste for global coverage will increase three times, reaching up to 155 - 265 tonnes metric annually in 2060. Aside from macroscopic plastic waste, 5.25 trillion plastic particles, estimated to be equal to 268,940 tonnes, will be distributed in the world's ocean [7].

As the problem of plastic waste might impact the land and ocean in the future, Indonesia and its great population took a step and formed a commitment with the world society to solve the issue of marine plastic waste. It was declared at three international summits (i.e. World Ocean Summit IV, UN Our Ocean Conference 2018, and G20 Summit in Germany). The decrease of plastic waste disposal was targeted at 70% of the total of Indonesia’s waste in 2025 [8]. We refer to the Ministry of Environment and Forestry of Indonesia that issued a presidential regulation (Peraturan Presiden Republik Indonesia Nomor 83 Tahun 2018) on the treatment of marine debris, containment strategies, programs, and synchronized actions which are measured and directed to reduce the total sum of marine debris, mainly plastic waste. The study of plastic waste includes strategic actions of SDGs in Indonesia based on the commitment to decrease the disposal. This movement has been supported to develop the pillar of environmental development [9] for ecosystems on land and below water. Indonesia’s government has prepared structured and integrated strategic actions, where one of its realizations is management of land waste disposal, followed by coastal and ocean, provided by research and location-based technology innovation.

Studying the plastic waste and how its growth could impact due to the increase of marine debris, researchers from Indonesia and other countries have studied its main impacts, for instance, to monitor the growth of population density [1,5,7,10,11]. Furthermore, the estimated daily plastic waste population in Asia is 1.2 kg, provided that Indonesia’s population would come up to 0.06 kg per day on average [1]. The massive population growth affects increasing plastic waste disposal. It is shown in the research about plastic waste disposal scenarios in the global scope, integrated with long-term projections of population and gross domestic products (GDP) [7]. Studies have defined the correlation between the population of one country and the plastic waste that flows to the ocean [1,5,7,10,11]. The study on the integration of land and ocean-based models was done by Lebreton in 2017, where it analyzed from the global model of waste management, population density, and hydrologic model, resulting in a model approach based on the integration of the land and the ocean [1,5,7,11,12].

Improving the approach of the study approach has been done due to obtaining more accurate models and coping up with wider coverage areas by remote sensing products. This solution comes from the major cause of plastic waste by the rising population and assumption of urban areas, which is assumed as the greater contributor to disposal [11]. Thus, the population is related to its economic condition and it becomes one of the factors [1,7]. These three major indicators could be integrated to provide potential value, and as a result, it might assume basic socioeconomic information that could be used to monitor plastic waste by its weight in kilogram or tonne using in situ data acquisition.

Based on the investigation and call for the actions though the plastic waste’s abatement commitment of Indonesia, this study aims to manage plastic waste based on its generation from the smallest administrative area in Indonesia. Using environmental, economic, and social aspects, the general vulnerability of plastic could be found by processing the secondary data of remote sensing products. Further, the potential area itself might be decided as policymakers require scientific data to mandate plastic waste, and will take further actions to uphold the pledge of 70% of plastic waste reduction by
2. Material and Methods

2.1. Data Used in This Study
To establish a study on the weight estimation of the plastic waste generation and its potential increasing disposal, which could define the socio-economic and urban area, this model uses location-based data. Considering the wide scope of Indonesia, secondary products of remote sensing are used to perform the analysis. Based on the literature study on plastic waste, there will be three major parameters to be considered: environmental aspects, social aspects, and economic aspects.

The study was divided into two major phases. The first phase is to study the data approach of plastic waste generation based on field measurement approaches from SIPSN (Information System of National Waste Management) [13] which was established by the Ministry of Environmental and Forestry of Indonesia. This phase object to analyzes the accepted data of waste generation per small administrative area of regency or city. However, to complete the approach data, we used a standardized approach from SNI (National Standard of Indonesia) which will be discussed more in the methodology. The data will provide the percentage of plastic waste generation per regency and total weight daily. To realize the spatial data, we used administrative boundaries from Indonesia’s National Mapping Agency (BIG) [14].

The second phase is to study the major potential and vulnerability of plastic waste generation growth per coverage area using the identification of data parameters. Three major aspects were reviewed by the secondary data, i.e. LULC from European Space Agency [15], population distribution provided from building dataset from OpenStreetMap [16], and product of nightlight separation of Visible Infrared Imaging Radiometer Suite from National Oceanic and Atmospheric Administration [17]. Environmental data were used in this study which is the level 1 product of ESA CCI-LC. It is derivative from AVHRR HRPT (1992 - 1999), SPOT-Vegetation (1999 - 2012) and PROBA-V (2013 - 2015) with the latest renewal in 2015 [15]. The social aspect was developed from building a dataset downloaded using Geofabrik [16]. This building dataset is interactive to be taken by its users from any major. The economic aspect is shown by using indirect parameters of nightlight from the product of VIIRS [17] which was observed monthly and renewal appears until now, however data used in 2019. Containing the unit of nightlight (nanoWatt x cm^{-2}/sr) which defined unit measurement of light in an area of resolution in Watt unit per the smallest area in cm^2 for every steradian angle condition (sr). The unit provided the assumption that the ball is measured by its steradian position. Nightlight data could result in the correlation of electricity access, while the power input realization was identified and increased for developing countries [18]. The nightlight data which will be processed was taken from Google Earth Engine, which requires the user to take the average radiant value, which has the brightest point on the range of May 2019.

To improve the result of the plastic waste disposal potential identification, we used a high-resolution population data from Facebook Connectivity Lab & CIESIN, which provided 30 m of spatial resolution [19]. And to overcome higher sensitivity data of urban areas, multi-products of LULC were used at the level of 300 m of resolution [15,20,21].

2.2. Methodology

2.2.1. Waste Generation Approaches
The study began by preparing the data approach to estimate the total sum of plastic waste weight in one regency based on its estimated population. The plastic waste generation data for each regency will be generalized for the whole administration area of its regency, defined by value on each pixel with a spatial resolution of 300 m. The general study is shown in figure 1 below.
Figure 1. General Schematic Methods of Developing Data Approaches of Plastic Waste.

Waste data management was cited from *Sistem Informasi Pengelolaan Sampah Nasional*/Information System of National Waste Management (SIPSN) [13], processed using tabulation-based data from field acquisition (in situ). Data processing was done by a tabulation-based software, enabling calculation of big data. SIPSN provided the waste generation for each capital of the city and non-capital, also the percentage of waste composition included leftovers, twigs, paper, metal, rubber, textile, plastic, and others. Although SIPSN was the main source of integrated waste data, it did not cover the data in all regencies. To solve this, we used other approaches that still based themselves on the SIPSN data as its benchmark.

Based on the population data [22], the second approach to compile waste and its composition data used sub-district approaches. The main idea was this process estimated the data in an unknown regency based on its total population, area, and neighborhood. The total waste generation will be obtained by calculating the average consumption of the sub-district population. This approach also obtained the composition by assuming the same number for its estimate.

Although these approaches might complete the data, waste data must be compared to the following aspects for each regency’s population. To conquer these problems, we used the standardized specification for waste generation in SNI 10-3983-1995 [23]. The standard of SNI identified the waste as its category of the city, i.e. small or moderate city, shown on the table below (Table 1). The final approach was mentioned to compare the actual data of waste generation data from SIPSN and sub-district approaches.
Table 1. Waste Generation by City Classification (SNI 10-3983-1995).

| No | Classification       | Volume (L/person/day) | Weight (kg/person/day) |
|----|----------------------|----------------------|------------------------|
| 1  | Moderate City        | 2.75 - 3.25          | 0.70 - 0.80            |
| 2  | Small City           | 2.5 - 2.75           | 0.625 - 0.70           |

2.2.2. Developing Potential Index of Plastic Disposal

As mentioned before, plastic waste disposal will be studied from three aspects, i.e. environmental, social, and economic. These parameters refer to data that contain urban areas and other areas that were placed by humans as the main factor of disposal and usage of plastic waste [1]. The indexing potential was done using LULC, population density, and nightlight.

Scoring data has been used to regard each potential data by using binary classification. This binary classification provided 1 for the potential classes and 0 for non-potential classes of data. The LULC products were defined to project and identify urban and developed areas. Identification was focused on the urban areas, and as a result, the other areas will be classified as non-potential. This processing has been done on the nightlight classification to define the economic aspect. Additionally, the VIIRS product or nightlight data could identify the economic value as a GDP product [24,25]. Nightlight processing used the geometrical interval classification method due to its suitability to group the economic activity [26]. Furthermore, the geometric interval could be concluded as the combination of the other classification such as natural breaks, quantile, and equal intervals. This method was focused on the distribution class provided with the exponential quantification principle and ideal distribution of data. As a result of the literature study, the higher economic activity brought the area to potential disposal.

For the social aspect, the population density was chosen to identify the high density due to the higher vulnerability. In population processing, we used the identification from building data of OpenStreetMap [16]. The basic form of building area by polygon transformed into point features, which used the centroid identification of the polygon. Adapting assumption one person for each polygon has been used because of no information available on the building’s classification. This value of building information was supported by the study which pledges to show its vulnerability per capita, as it showed the plastic waste generated by each person. The point features that containing a value calculated using the density principle, which provides calculation and analysis spatially based on certain areas. The method that we used was calculating points per 1-pixel coverage in 300 x 300 m. The population density was classified using the reference from the standardised classification of population density by SNI 03-1733-2004 [27] which contained environmental household planning procedures in the urban areas. The classification showed in Table 2 below. For the population, the population will be more vulnerable in high-density population where the higher population density was one of the contributors of waste disposal [5,10].

Table 2. Population Density Classification (SNI 03-1733-2004).

| Region Classification | Low          | Mid            | High          | Very High     |
|-----------------------|--------------|----------------|---------------|---------------|
| Population Density    | <150 person/ha | 151 - 200 person/ha | 201-400 person/ha | >400 person/ha |
The class arrangement is based on intervals that have considered the weight, and as a result, it can assess qualitatively: low, moderate, and high. These three aspects were calculated and resulted in an index for 300 m spatial resolution between 0 to 3, providing representation of each potential.

3. Result

3.1. Plastic Waste Generation Model per Administrative Area
The result referenced to SIPSN was taken from data by the period of 2017 to 2018. Results showed in ton per day with an indication of the same value per regency.

Figure 2. Plastic Waste Generation per Regency.

Results in figure 2 showed that the range total of plastic waste generation per administrative area of regency or city in tonne daily. The highest point of plastic waste weight was implemented in Bogor Regency at Java Island with an estimated total of about 954.4656 tonnes per day. In contrast, the lightest plastic waste was in Selayar Islands (South Sulawesi Province) where the plastic waste generation was approximately 1.18526 tonnes per day. Based on Table 3 below, the highest numbers were most common in West Java Province due to the metropolitan cities themselves.
Table 3. 20 Regencies with The Highest Plastic Waste.

| No | Regency/City         | Province        | Population (2019) | Category    | Waste Generation  | Plastic Waste  |
|----|----------------------|-----------------|-------------------|-------------|-------------------|---------------|
| 1. | Bogor                | West Java       | 5,965,410         | Metropolitan| $4.7 \times 10^3$ | $0.95 \times 10^3$ |
| 2. | Tangerang            | Banten          | 3,800,787         | Metropolitan| $3.04 \times 10^3$ | $0.62 \times 10^3$ |
| 3. | Bandung              | West Java       | 3,775,280         | Metropolitan| $3.02 \times 10^3$ | $0.61 \times 10^3$ |
| 4. | Bekasi               | West Java       | 3,763,890         | Metropolitan| $3.01 \times 10^3$ | $0.602 \times 10^3$ |
| 5. | Kota Jakarta Timur   | DKI Jakarta     | 2,937,859         | Metropolitan| $2.4 \times 10^3$  | $0.51 \times 10^3$ |
| 6. | Kota Surabaya        | East Java       | 2,896,000         | Metropolitan| $2.3 \times 10^3$  | $0.45 \times 10^3$ |
| 7. | Kota Jakarta Barat   | DKI Jakarta     | 2,589,933         | Metropolitan| $2.07 \times 10^3$ | $0.44 \times 10^3$ |
| 8. | Garut                | West Java       | 2,622,430         | Metropolitan| $2.1 \times 10^3$  | $0.43 \times 10^3$ |
| 9. | Tasikmalaya          | West Java       | 1,754,130         | Metropolitan| $1.4 \times 10^3$  | $0.42 \times 10^3$ |
| 10.| Kota Bekasi          | West Java       | 3,003,920         | Metropolitan| $2.4 \times 10^3$  | $0.41 \times 10^3$ |
| 11.| Kota Jakarta Selatan| DKI Jakarta     | 2,264,699         | Metropolitan| $1.8 \times 10^3$  | $0.39 \times 10^3$ |
| 12.| Indramayu            | West Java       | 1,728,470         | Metropolitan| $1.4 \times 10^3$  | $0.35 \times 10^3$ |
| 13.| Deli Serdang        | North Sumatera  | 2,195,709         | Metropolitan| $1.8 \times 10^3$  | $0.33 \times 10^3$ |
| 14.| Malang               | East Java       | 2,606,000         | Metropolitan| $2.08 \times 10^3$ | $0.32 \times 10^3$ |
| 15.| Kota Jakarta Utara  | DKI Jakarta     | 1,812,915         | Metropolitan| $1.5 \times 10^3$  | $0.31 \times 10^3$ |
| 16.| Sukabumi             | West Java       | 2,466,270         | Metropolitan| $1.9 \times 10^3$  | $0.307 \times 10^3$ |
| 17.| Sidoearlo            | East Java       | 2,249,000         | Metropolitan| $1.8 \times 10^3$  | $0.304 \times 10^3$ |
| 18.| Gresik               | East Java       | 1,313,000         | Metropolitan| $1.05 \times 10^3$ | $0.29 \times 10^3$ |
| 19.| Kota Tangerang Selatan| Banten        | 1,747,906         | Metropolitan| $1.39 \times 10^3$ | $0.284 \times 10^3$ |
| 20.| Banyuwangi           | East Java       | 1,614,000         | Metropolitan| $1.29 \times 10^3$ | $0.281 \times 10^3$ |

Referring to the results, plastic waste generation became higher as the population increases. It showed that Bogor Regency, with the highest population in Indonesia of 5,965,410 population, defined approximately 2100 population per km$^2$ for its density. It was directly proportional to Selayar Islands with the lowest occupants of the 13,208 population and, regarded as the lowest production of plastic waste.
Figure 3. The Highest Plastic Waste Generation Located in Java Island.

Plastic waste generation represented for each regency was improved by approaches and related aspects of population identification from SNI. Figure 3 above showed the area which was regarded as the biggest contributor, specifically on Java Island. The regencies and one province (DKI Jakarta) are all categorized as the metropolitan with the range of plastic waste 835 to 954 tonne for daily consumption.

3.2. Potential Index of Plastic Waste Disposal
The potential index was formed from three aspects parametric data, i.e. LULC, population density, and nightlight, resulting in an index with the unit of the data parameter. Each potential from each data parameter represented the value of 1 index, shown in Figure 4 below. The results provided two approaches with different population data products.

Figure 4. Identified Metropolitan Categorised from First Approach Index.

The first approach (section A, figure 4 and 5) used LULC [15], generated population density from buildings [16], and nightlight [17]. The plastic waste potential index visualized and identified areas that
have the potential to provide a large opportunity for plastic waste disposal. Reviewed from the results, the potential index illustrates areas categorized as big cities (for example, DKI Jakarta and Makassar City) marked by variations in the index around and there is a maximum potential index, which reaches number 3. The plastic waste potential index is comprehensive and applies to all regions in Indonesia. The preview seen in figure 4 shows that the high index is directly proportional to the urgency of handling plastic waste disposal in the area assuming high economic activity is supported by high population density in urban areas. Quantitatively reviewed by the large area of each index, the index has a tendency of 0 with a percentage of 94.54% of the total area of Indonesia. Index 0 means that in this area, it is not an urban area, high population density, or high economy for the first approach.

![Diagram of potential index]

**Figure 5.** Potential Index of Plastic Waste Disposal in Two Approaches.

The development of a potential index for the emergence of plastic waste was developed with a population data product with a spatial resolution of 30 m [19] to obtain the identification of residential areas in non-urban and urban areas. In this second approach of indexing, data was collected by combining urban land cover data products [15,20,21] with population data products, then indexes were calculated by identification of economic activity by nightlife data. Calculations produce indexes with a comparison with the previous region shown in figure 5 in section B. This described an area with high-resolution population data development, where A was the potential index generated in the study and B was the potential index with the development of population data products. Visually, the area will be more sensitive to the classification of residential areas, but the concentration of identification of areas that were increasingly densely populated was not found, where the index value of 3 was not identified on the results of the development index. However, consideration of identifying non-urban residential areas needs to be identified.
The index itself could be used as the identification of the metropolitan areas. Shown in Figure 5 on the A and B approaches, i.e. Jakarta Province and Makassar City, which have high populations and high economic activities on the urban level.

4. Discussion
The aspects used in this research are represented by using land-cover land use data for the environment as identification of urban areas, population density developed through building data development, and economic studies using nightlight data. The reliability of the data from the land-use cover of the CCI-LC ESA product has a spatial resolution of 300 m with the latest data updated 2015. The use of this data only involves urban areas and there is no comparable data with other land-use covers. The indications that non-urban areas have a share of waste disposal are not managed by the activities carried out [2].

Population density derived from building data available on the OpenStreetMap [16] has insufficient evidence assuming one building consists of one person. So, the accuracy of the data and the results of the population at each pixel are not real data. Consideration must be given to each building by type of building, if it is a settlement, an assumption can be made on the number of people residing. However, assuming one building one person can provide a visualization of the distribution of density in terms of data even though it cannot accurately assume population density with its data patterns.

Night light data which is a VIIRS product can represent the economy by giving a picture of GDP predictions which are predictions of per capita income [24,25]. The logic developed between the unit of GDP and the night light is the value of GDP which is a unit that can represent the progress of a region (in USD), while the night light has a strong association regarding the indication of economic status by indicating economic activities such as industry and population. [28].

Predicted by using linear regression to polynomials which have been done by some researchers [24,25], the night light can predict GDP well by analyzing light to the city level. This assumption is in line with the use of plastic waste data with the smallest regency/city scale, but it still needs a literal GDP data to get a potential classification.

The assumptions developed in this research are plastic waste which is discarded and not treated into the river based on a presentation. Assumptions are supported by weights obtained from three aspects of the index. There is a step that is not done, which is comparing land cover products, where non-urban areas are needed. The assumption built in this research is to focus on plastic growth in general, regardless of the type of resource management, where there are indications of production [1] as well as indications of industrial growth, as does the growth of the plastic user industry. The development of the beverage industry can lead to increased production of plastic waste, which can lead to increased consumption of plastic waste. With the growth of the packaging beverage industry reaching 24.4% on an annual basis [29], this fact shows that this research cannot be exceeded. Where the uniform assumptions of each region with residential land cover are considered to have the same weight value.

The indexing methods which were mentioned used the binary classification, which might have some inaccuracies on the vulnerability. However, it has shown that the index result could show the vulnerability of the following studies. This study found that for metropolitan cities like Central Jakarta, Makassar, Bandung, Medan could be easily identified based on the indexing methods. Which this index shows the elaboration with the data approaches of plastic waste generation on the first results of the plastic waste generation model.

5. Conclusion
The role of parameter data covering three aspects, i.e. environmental, social, and economic, explains, in general, the area with the identification of areas of scenario with high human activity accompanied by a relatively dense population density. The resulting index immediately comes from the highest potential value using a two-choice pattern like a binary number, potential or not. This is a simple illustration to provide a pattern of distribution of high potential until there is no potential associated with massive plastic waste production.
Index development needs to be done by reviewing other environmental aspects such as rainfall, where rainfall is one of the factors of the higher production of plastic waste [11]. As for the need for the development of data on approaches to waste production up to the most updated year. To assume economic aspects, it is necessary to conduct a review using quantitative GDP data so that areas with good economics up to low quality can be obtained, as well as population data with per pixel scenarios. Further research is needed related to driving factors so that the estimated volume of waste can be produced more accurately.

References
[1] Jambeck J R, Geyer R, Wilcox C, Siegler T R, Perryman M, Andrady A, Narayan R and Law K L 2015 Plastic waste inputs from land into the ocean Science Mag. 347 Issue 6223 768–70
[2] Barnes D K A, Galgani F, Thompson R C and Barlaz M 2009 Accumulation and fragmentation of plastic debris in global environment Philos. Trans. R. Soc. Lond. B. Biol. Sci. 364 (1526) 1985–98
[3] Brooks A L, Wang S and Jambeck J R 2018 The Chinese import ban and its impact on global plastic waste trade Sci. Adv. 2018 4 1–7
[4] Gall S C and Thompson R C 2015 The impact of debris on marine life Mar. Pollutn. Bltin. 2015 1–10
[5] Lebreton L C M, Zwet J van der, Damsteeg J, Slat B., Andrady A and Reisser J 2017 River plastic emissions to the world’s oceans Ntre. Comm. 8:15611 1–10
[6] Pravettoni R 2018 Plastic waste produced and mismanaged https://www.grida.no/resources/6931 accessed on 19th April 2020 at 19.20
[7] Lebreton L and Andrady A 2019 Future scenarios of global plastic waste generation and disposal Palgrave Comm. 5 No. 6. 1–11
[8] European Commissioner for Environment (ECC) 2017 Maritime Affairs and Fisheries Report Our Ocean
[9] Kementerian Perencanaan Pembangunan Nasional Republik Indonesia/Badan Perencanaan Pembangunan Nasional 2018 Sustainable Development Goals (Jakarta: Kementerian Perencanaan Pembangunan Nasional Republik Indonesia/Badan Perencanaan Pembangunan Nasional)
[10] Cózar A, Echevarria F, González-Gordillo, J I, Irigoien X, Úbeda B, Hernández-León S, Palma Á T, Navarro S, García-de-Lomas J, Ruiz A, Fernández-de-Puelles M L and Duarte C M 2014 Plastic debris in the open ocean PNAS 111 No. 28 10239–44
[11] Cordova M R and Nurhati I S 2019 Major sources and monthly variations in the release of land-derived marine debris from the Greater Jakarta area, Indonesia Sciif. Rep. 9:18730, 1–8
[12] Moy K, Neilson B, Chung A, Meadows A, Castrence M, Ambagis S and Davidson K 2017 Mapping coastal marine debris using aerial imagery and spatial analysis Mar. Polltn. Bltin. 2017 1–8
[13] Kementerian Lingkungan Hidup dan Kehutanan 2018 Data Pengelolaan Sampah [Internet]. sipsn.menlhk.go.id [cited 10th January 2020]. Available from: http://sipsn.menlhk.go.id/10
[14] Badan Informasi Geospasial Peta Rupabumi Indonesia [Internet]. tanahair.indonesia.go.id [cited 10th January 2020]. Available from: https://tanahair.indonesia.go.id/portal-web
[15] ESA Climate Change Initiative 2015 CCI-LC Products [Internet]. esa.landcover-cci.org [cited on 21st January 2020]. Available from: https://www.esa-landcover-cci.org/?q=node/164
[16] Open Street Map 2019 GEOFABRIK Downloads: Asia [Intenet]. download.geofabrik.de [cited on 24th March 2020]. Available from: http://download.geofabrik.de/asia.html
[17] National Oceanic and Atmospheric Administration Earth Engine Catalog: VIIRS Nighttime Day/Night Band Composites Version 1 [Internet]. developers.google.com [cited on 9th February 2020]. Available from: https://developers.google.com/earth-engine/datasets/catalog/NOAA_VIIRS_DNB_MONTHLY_V1_VCMCFG?hl=en
[18] Beyer R C M 2017 Growth Out of The Blue Worldbank: South Asia Economic Focus Fall 2017 1–22
[19] Facebook Connectivity Lab and Center for International Earth Science Information Network CIESIN - Columbia University 2016 High Resolution Settlement Layer (HRSL) Source imagery for HRSL © 2016 DigitalGlobe. accessed on 1st May 2020
[20] MODIS 2020 MODIS/Terra+Aqua Land Cover Type Yearly L3 Global 500m SIN Grid V006 https://catalog.data.gov/dataset/modis-terraaqua-land-cover-type-yearly-l3-global-500m-sin-grid-v006, accessed on 1st May 2020
[21] United Nations Office for Outer Space Affairs 2020 Global Map-Global Land Cover (GLCNMO) (ISCGM) http://www.un-spider.org/links-and-resources/data-sources/global-map-global-land-cover-glcno-iscgm, accessed on 1st May 2020.
[22] Badan Pusat Statistik 2019 Statistik Indonesia 2018 [Internet]. bps.go.id [cited on 10th January 2020]. Available from: https://www.bps.go.id/
[23] -- Spesifikasi Timbulan Sampah Kota Sedang dan Kota Kecil SNI 10-3983-1995 1995 (Jakarta: Badan Standardisasi Nasional)
[24] Dai Z, Hu Y and Zhao G 2017 The Suitability of Different Nighttime Light Data for GDP Estimation at Different Spatial Scales and Regional Levels Sustainability 2017 9 305 1–15
[25] Hu Y and Y Jiaxiong 2019 Illuminating Economic Growth 2019 International Monetary Fund Working Paper 19/77 1–56
[26] Olanrewaju L and Babatunde N O 2015 Spatial Modelling Of Economic Activity in Nigeria Using Gross Domestic Product of Economically Active Population IOSR Journ. Of Hmnts. And Soc. Sci. (IOSR-JHSS) 20 Issue 4 Ver. 1 pp 66–72
[27] -- Tata Cara Perencanaan Lingkungan Perumahan di Perkotaan SNI 03-1733-2004 2004 (Jakarta: Badan Standardisasi Nasional)
[28] Forbes D J 2013 Multi-scale Analysis of the Relationship between Economic Statistics and DMSP/OLS Night Light Images GISci Rem. Sens. 2013 50 483–499
[29] Pemerintah Pusat Indonesia Portal Informasi Indonesia 2019 Menenggelamkan Pembuang Sampah Plastik di Laut [Internet]. indonesia.go.id [cited on 31st March 2020]. Available from: https://www.indonesia.go.id/narasi/indonesia-dalam-angka/sosial/menenggelamkan-pembuang-sampah-plastik-di-laut