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A Novel Formulation of Ecosystem Health Index in Urban Areas of Java Island, Indonesia

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Abstract

Quantitative assessment of ecosystem health in Indonesia is determined by water quality, air quality and forest cover condition. However, it is unable to describe the ecosystem quality completely. Therefore, we propose three additional parameters to complement the current ecosystem health index to be a novel ecosystem health index in Indonesia. This research aimed to formulate quantitative approaches of urban ecosystem health assessment as a basis of calculation and formulation of national ecosystem health assessment and to calculate urban ecosystem health in selected municipalities in Java Island Indonesia, namely Gunung Kidul, Sleman, Batu, Blitar, Mojokerto, Tangerang, and Tegal. The chosen locations were based on geographical location distribution and the comprehensiveness of the required data. This research was carried out during March-May 2020 by direct measurement and completed by secondary data. Six parameters determined a novel formulation of ecosystem health index completely including air quality index (AQI), water quality index (WQI), forest cover index (FCI), biodiversity index (BDI), public health index (PHI) and environmental health index (EHI). Based on data assessment, ecosystem health index of Gunung Kidul was 66.75, Sleman was 68.64, Batu was 77.64, Blitar was 67.22, Mojokerto was 66.35, Tangerang was 54.39, and Tegal was 57.46.

Keywords - ecosystem, ecosystem health index, Java Island, urban area.

I. INTRODUCTION

Nowadays, people in the world are facing several complexes, uncertain, and intermittent environmental problems. The adaptation strategies include building infrastructure, changing socio-economic behaviours, or using natural resources [1]. A healthy ecosystem is a fundamental guarantee for the sustainable development of society and economy, and the primary condition for human survival [2]. An ecosystem is a system where interactions between organisms and their environment occurred. According to Filho *et al.* [3], ecological restoration and ecosystem rehabilitation in urban areas such as rivers, lakes, and vegetated areas are quite often economically advantageous. Urban green and blue spaces play an essential role in the sustainability and resilience of those cities.

Ecosystem health assessment is one of many tools to analyze ecosystem sustainability. Ecosystem health assessment in Indonesia is based on Environment Quality Index (EQI), which describes the condition of water quality, air quality and forest cover quality. Those three parameters were deemed unable to describe the ecosystem quality completely. The reason was that the ecosystem is not only influenced by biotic component. It is determined by abiotic components too that have a direct impact on ecosystem sustainability [4].

This research was the improvement of EQI by adding three more parameters to complement the current index. Those parameters are biodiversity index (BDI), public health index (PHI) and environment health index (EnHI). This research aimed to formulate a quantitative assessment of ecosystem health in an urban area as a basis of national ecosystem health calculation and assessment and to calculate ecosystem health index in Gunung Kidul Regency and Sleman Area and urban areas in Java Island such as Batu Municipality, Blitar Municipality, Mojokerto Municipality, Tangerang Municipality and Tegal Municipality.

II. MATERIALS AND METHOD

The research was carried out in March-May 2020. Fig 1 shows the locations where this research took place. The locations were chosen based on geographical location distribution and the comprehensiveness of required data.

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Figure 1: Map of research locations in Java Island, Indonesia

Instruments and materials used in NO_2 measurement referred to SNI 7119.2-2005 [5], while the ones used in SO_2 measurement referred to SNI 7119.7-2005 [6]. Tools used in BDI measurement were cellphone camera and writing tools such as paper and pen while the equipment was a land lot with 10 m length and 10 m width. Other instruments and material used in this research were secondary data from Regional Living Environment Management Performances Information, Regional Living Environment Status, Indonesia Public Health Profiles and Statistical Information References System. The primary and secondary data were processed using *Microsoft Excel*.

The research was carried out by direct measurement and followed by data collection, which was subsequently processed according to EQI methods. The weighting factor of each component is 16.7%. Initial EQI parameters are shown in Table 1, while three additional parameters are shown in Table 2.

Table 1: Initial EQI parameters

EQI Parameters	Air Quality Index (AQI)	Water Quality Index (WQI)	Forest Cover Index (FCI)
Parameter	SO_2 and NO_2	TSS, DO, COD	Primary forest area and secondary forest area
Weighting factor (%)	30	30	40
Reference	Govt. Reg. No. 41/1999	Govt. Reg. No. 82/ 2001	-

Source: The Ministry of Environment and Forestry, Indonesia [7]

Table 2: Three proposed additional EQI parameters

Parameters	Biodiversity Index (BDI)	Public Health Index (PHI)	Environmental Health Index (EHI)
Parameter(s)	Number of species or individual	Mortality rate, morbidity rate, life expectancy and nutrition status	Access to clean water, healthy house, and access to basic sanitation
Weighting factor (%)	16.7	16.7	16.7
Reference	Shannon-Wiener Index	Indonesia Health Profile	Indonesia Health Profile

Direct measurements were done to measure the parameters of AQI and BDI in Sleman Regency while the rests were measured indirectly. Equation (1) was used to calculate AQI by using European Union version of the air pollution index (IEU). API of each parameter is the ratio between average concentration and EU reference score that is shown in Table 2. The IEU was calculated using Equation (2).

$$AQI = 100 - \left(\frac{50}{0.9}\right) x(IEU - 0.1) \quad (1)$$

$$IEU = \frac{API\ NO2 + API\ SO2}{2} \quad (2)$$

Where API (air pollution index) is pollution index of each pollutant, WQI was calculated using PI (pollution index) notation according to Annex II of The Decree of Minister of Environment Affairs No. 115. PI was found by Equation (3).

$$PIj = \sqrt{\frac{\left(\frac{Ci}{Lij}\right)^2 m + \left(\frac{Ci}{Lij}\right)^2 r}{2}} \quad (3)$$

FCI, BDI, PHI and EHI was calculated based on secondary data. Forest cover was calculated using Equation (4), while FCI was calculated using Equation (5).

$$FC = \frac{PFA+SFA}{TA} \quad (4)$$

$$FCI = 100 - (84.3 - (FC\ x\ 100)x\frac{50}{54.3} \quad (5)$$

Where FC is forest cover, PFA is a primary forest area, SFA is a secondary forest area, and TA is municipality area. BDI, which is stated in the Shannon-Wiener Index [8], was calculated using Equation (6).

$$H' = -\sum_{i=1}^{n}(pix\ln pi) \quad (6)$$

Remarks: *pi* is the ratio between individual of a species and the total number of individuals.

The public health index was calculated based on four parameters, namely morbidity, mortality, life expectancy and nutrition status. EHI was calculated with three parameters, namely people with clean water access, healthy house, and people with basic sanitation access. EHI is the average of those three parameters. Then, the correlation between each ecosystem health index component was analyzed using ANOVA *one-way* method. ANOVA *one-way* is a technic to compare the average of two or more sample. Then F-ratio was calculated. F-ratio is comparison number between the mean square of a group and means square of another group. F was compared with F_{crit}. There are two possibilities [9]:

1. If $F < F_{crit.}$: H_o is accepted
2. If $F > F_{crit.}$: H_o is rejected.

III. RESULT AND DISCUSSION

Ecosystem Health Index (EHI)

The healthy ecosystem must have the ability to do ecological services for human life and to maintain its development sustainability [10. Ecosystem health describes how the entire processes that work in the ecosystem are functioned to empower the existing system [11]. According to Radeva *et al.* [12], a healthy ecosystem is determined by productivity, diversity, and sustainability. Ecosystem health index is a mechanism in assessing the health level of a system, including impacts on the environment [13]. More parameters produce a better analysis with a strong prediction of how each parameter represent a region. EQI ranges between 0 and 100. A higher index indicates a better quality of each parameter [7]. Table 3 shows the calculation result of EHI. A region with the highest EHI was Batu Municipality with 66.75 while the lowest was Tangerang Municipality with 54.39.

Table 3: Calculation results of EQI with three added parameters

No	Municipality	AQI [a]	WQI [b]	FCI [c]	BDI [d]	PHI [e]	EnHI [f]	EHI
1	Gunung Kidul	61.44	70.00	31.28	64.95	91.17	81.66	66.75
2	Sleman	63.29	70.00	25.66	85.05	88.17	79.81	68.64
3	Batu	85.42	53.43	73.86	67.93	91.91	93.27	77.64
4	Blitar	85.81	62.31	22.38	62.69	83.20	86.93	67.22
5	Mojokerto	93.20	50.00	22.38	57.85	89.18	85.49	66.35
6	Tangerang	45.80	46.00	22.38	60.45	90.89	56.84	54.39
7	Tegal	72.84	51.33	22.75	71.66	92.42	33.75	57.46

[a] AQI: Air Quality Index, [b] WQI: Water Quality Index, [c] FCI: Forest Cover Index, [d] BDI: Biodiversity Index, [e] PHI: Public Health Index; [f] EnHI: Environmental Health Index

Air Quality Index (AQI)

Ambient air quality is the primary parameter to understand the effects of air pollution on the environment [14]. The increasing level of SO_2, NO_2 and CO concentration in the atmosphere is the key factor of global warming [15]. The calculation results of AQI shows a region with the highest AQI was Mojokerto Municipality with 93.20 while the lowest was Tangerang Municipality with 45.80. AQI is determined by SO_2 and NO_2 ambient air concentration. The average concentration of SO_2 and NO_2 in Mojokerto was 5.89 μg/m^3 and 6.05 μg/m^3, respectively, whereas in Tangerang were 24.30 μg/m^3 and 21.35 μg/m^3, respectively. NO_2 and SO_2 average concentration of each municipality is shown in Fig 2.

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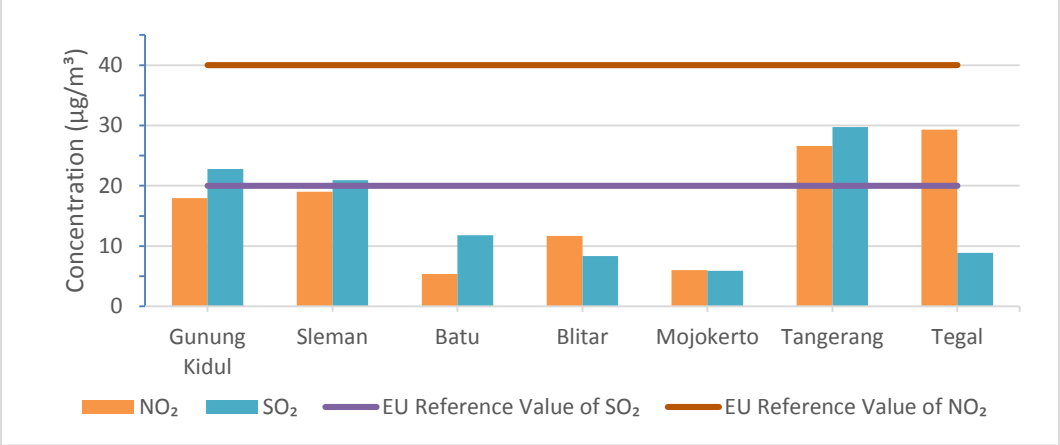

Figure 2 NO_2 and SO_2 average concentration of each municipality

According to KLHK (2018), NO_2 concentration represents the emission of the gasoline-fueled vehicle, while SO_2 concentration represents the emission of diesel-fueled vehicle. The most significant source of pollutants in Tangerang is the industrial sector, which produces 90% pollutants, including NO_x, CO, SO_2, HC, PM_{10}, $PM_{2.5}$ and Pb [16]. The concentration of SO_2 in Gunung Kidul Regency was above the standard, with 22.78 µg/m^3. One of the causes was the high amount of vehicle. According to Juniati and Dwitasari [17], a tourist destination in Gunung Kidul Regency is massive growth and followed by high traffic density.

Water Quality Index (WQI)

Water quality assessments are necessary to identify issues related to water contamination [18]. Data calculation of WQI shows Gunung Kidul and Sleman Regencies have the highest score with 70.00 while Tangerang and Mojokerto Municipalities have the lowest score with 50.00. WQI is determined by COD, TSS and DO concentration, and the assessment is based on the pollution index of each parameter. Lower pollution index reflects a better river water quality. The calculation referred to Indonesian Government Regulation Number 15/2003, as shown in Table 4.

Table 4: Number of water quality control point according to PI evaluation

Municipality	No. of Control Point	Criteria			
		Meet Quality Standard	Lightly Polluted	Moderately Polluted	Heavy Polluted
Gunung Kidul	6	6	-	-	-
Sleman	120	120	-	-	-
Batu	35	8	25	2	-
Blitar	26	20	3	2	1
Mojokerto	8	-	8	-	-
Tangerang	5	1	3	1	-
Tegal	15	1	14	-	-

Decreasing water quality is mainly caused by human ignorance to the environment and the sustainable development aspects [19]. According to Dawud [20], river pollution in Tangerang Municipality mainly affected by domestic and industrial waste and other activity which cause health problems. Organic matters contained in river water were affected by wastewater and vegetation cover [21].

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Forest Cover Index (FCI)

The forest ecosystem is one of the natural resources that produce multiple advantages for the people [22]. According to Canetti *et al.* [23], existing urban forests offer a better life for the citizen. Green area reduces dementia and stroke risk [24]. Comparison of forest cover area of each municipality is shown in Table 3.

Table 3: List of municipalities by vegetated land area

No	Municipality	Vegetated Area (ha)	Total area (ha)
1	Gunung Kidul	88.578	148.536
2	Sleman	29.789	57.482
3	Batu	17.050	20.280
4	Blitar	1.107	3.257
5	Mojokerto	704	1.647
6	Tangerang	4.572	16.455
7	Tegal	1.256	3.968

Batu Municipality has the highest forest cover with 73.86. Approximately 55.91% of Batu Municipality area was covered by vegetation. According to Soekmana [25], Batu was the primary city in the development of ecotourism in East Java. Blitar, Mojokerto and Tangerang have the lowest forest cover with 22.38 because the respective areas are not covered by forest. According to Swedan [26], the decreasing forest area is affected by population growth.

Biodiversity Index (BDI)

Biodiversity strengthen ecosystem security from climate phenomenon threats [27]. A high combination of species in just a few kilometres square of urban areas is the main reason why most of the biodiversity research took place in urban areas [28]. According to Eriksson and Hillebrand [29], biodiversity contributes to ecosystem process, especially in keep its stability either spatially or temporally. Sleman Regency has the highest biodiversity index with 85.05. Calculation of biodiversity index was done in plant species. There were 21 species and 36 individuals found in research location which is dominated by *Swietenia mahagoni.* Shannon-Wiener index of Sleman Regency was 2.92, higher than other research locations. Biodiversity in Batu Municipality was measured in *pteridophyte* species [30].

Public Health Index (PHI)

According to Wells and Donofrio [31], environment and public health are positively related. Low life expectancy is usually associated with a poor health condition [32]. PHI is determined by four parameters, namely morbidity rate, mortality rate, life expectancy and nutrition status. Mojokerto Municipality has'. It is mainly caused by low, ill population in the area. Only 7.569 ill cases of its 126.404 population were documented in Mojokerto. The calculation result of each PHI parameters is shown in Fig 3. The life expectancy was 72.86 years old, and there was no malnutrition case in Mojokerto. The area with the lowest PHI was Blitar Municipality with 83.20. The mortality rate in the area was high, with 95.650 documented cases of its 139.117 population.

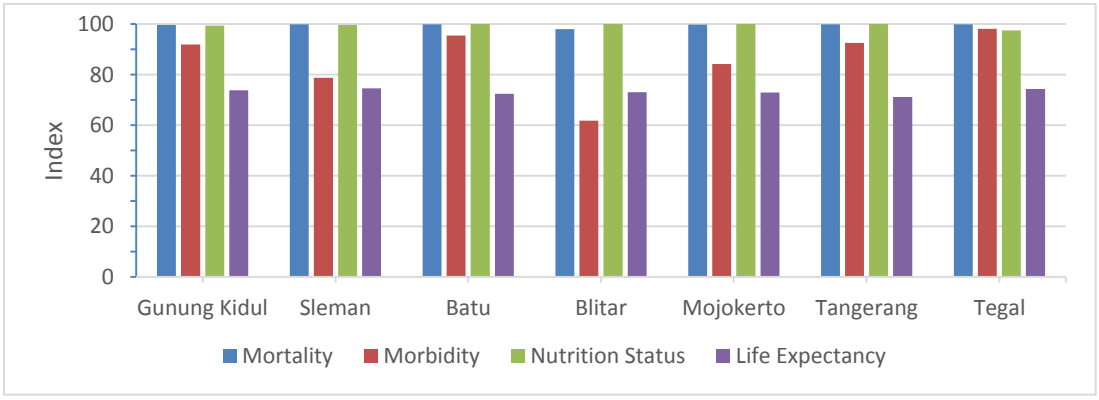

Figure 3: Calculation result of each PHI parameters

Tegal Municipality and Gunung Kidul Regency have the worst nutrition status. The number of kids with malnutrition case in Tegal was 2.50% while in Gunung Kidul were 0.60%. The main factor of kid malnutrition was smoke exposure. According to the Ministry of Health (2013), approx. 74.3% of Tegal population were smokers. Gunung Kidul Regency is not better than Tegal. Free smoke households in Gunung Kidul remain low, with only 40.2% [33].

Environmental Health Index (EnHI)

Three parameters determine EHI. Those are the percentage of the population with clean water access, the percentage of healthy house and percentage of the population with primary

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sanitation facility. Inadequate sanitation and clean water facility increase the risk of diarrhoea [34].

Batu Municipality has the highest EnHI with 93.27. Around 85.36% of Batu population have access to clean water while around 97.85% of houses in Batu considered as a healthy house. Tegal Municipality has the lowest EnHI with 33.75. It was mainly caused by low healthy house percentage. Only 2.178 of 66.219 houses in Tegal are considered a healthy house. The score of each EnHI parameters is shown in Fig 4.

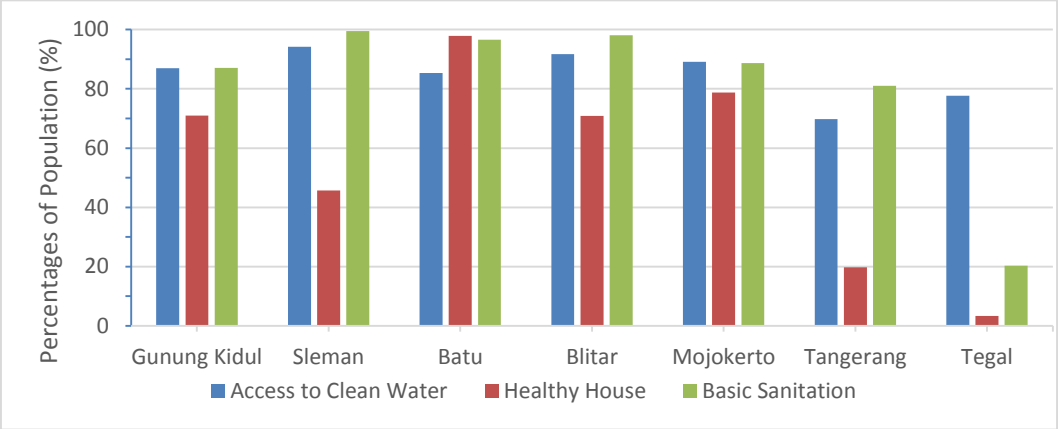

Figure 4: Score of EnHI parameters

Table 4: Correlation of each parameter based on the determination coefficient (R^2)

Parameter	WQI	FCI	BDI	PHI	EnHI
AQI	0.047	0.078	0.024	0.101	0.206
WQI		0.010	0.279	0.128	0.147
FCI			0.005	0.133	0.197
BDI				0.000	0.019
PHI					0.189

Correlation Between Parameters

Correlation between parameters used in LEHI calculation was described in the determination coefficient (R^2). The purpose is to describe the equality between green issues (biotic resources) and brown issues (abiotic resources) (KLHK 2018). The correlation of each parameter based on the determination coefficient is shown in Table 4.

According to the result shown in Table 8, FCI-EHI has highest R^2 with 0.197, which indicates that FCI and EHI have the strongest correlation than other parameters. Correlation between FCI and EHI is shown in Fig 5.

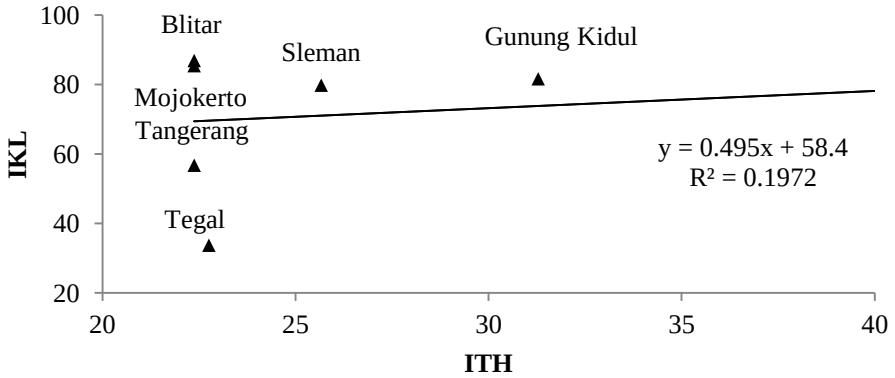

Figure 5: Correlation chart between FCI and EHI

Table 5: ANOVA test of FCI-EHI

Source of Variation	SS	Df	MS	F	P-value	F_{crit}
Between Groups	6.303	1	6.393,62	15.66	0.0019	4.75
Within Groups	4.831	12	492.64			
Total	11.135	13				

However, it is not strong enough to represent the correlation between the two parameters. The result had to be improved with a one-way ANOVA test. ANOVA test is a hypothetical test where the conclusion was resulted based on inferential statistic data or group [35]. One-way ANOVA test of FCI-EHI is shown in Table 5.

The calculation shows $F<F_{critical}$, that means FCI-EHI has strong correlation statistically. H_0 took for all parameters is similar that every parameter has a strong correlation. According to the one-way ANOVA test, a strong correlation is shown between AQI-WQI, AKI-BDI, AKI-EnHI, WQI-BDI, WQI-EnHI, BDI-EnHI and EnHI-PHI. Whereas AQI-FCI, AQI-PHI, WQI-FCI, WQI-PHI, FCI-PHI, FCI-BDI, FCI-EnHI, and BDI-PHI have a weak correlation. It concludes that the determination coefficient could not determine how strong two parameters are correlated. AQI-BDI which has R^2 0.024 are regarded has strong correlation according to one-way ANOVA test while PHI-WQI which has higher R^2 with 0.128 are regarded has weak correlation according to one-way ANOVA test.

IV. CONCLUSION

Based on the explanation above, it is concluded that six parameters determined the novel formula of ecosystem health index, namely air quality index (AQI), water quality index (WQI), forest cover index (FCI), biodiversity index (BDI), public health index (PHI) and environmental health index (EHI). Based on the novel system, it reveals that ecosystem health index in Gunung Kidul was 66.75; Sleman was 68.64; Batu was 77.64; Blitar was 67.22; Mojokerto was 66.35; Tangerang was 54.39, and Tegal was 57.46.

It is now possible to implement the novel formulation of the ecosystem health index to substitute the conventional system one. An extension application of the novel system in other islands in Indonesia needs a series of data compilation as well as direct sampling in the field.

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REFERENCES

[1] Fedele G, Locatelli B, Djoudi H, Colloff MJ. 2018. Reducing risks by transforming landscapes: Cross-scale effects of land-use changes on ecosystem services. PLos ONE. Vol 13(4): 1-21.

[2] Liu P, Rong L, Teng F. 2018. The evaluation of ecosystem health based on hybrid TODIM method for Chinese case. *Journal of Technological and Economic Development of Economy*. Vol 25(3): 542-570.

[3] Filho *et al.* 2020. Reviewing the role of ecosystems services in the sustainability of the urban environment: A multi-country analysis. *Journal of Cleaner Production.* 121338.

[4] Folmer F, Schumacher M, Jaspars M, Dicato M, Diederich M. 2009. *Chemical Ecology and Medicinal Chemistry of Marine NF-KB Inhibitors.* New York (US): Nova Scotia Publishers.

[5] [BSN] Badan Standardisasi Nasional. 2005a. SNI 19-7119.2-2016. *Penentuan Konsentrasi Nitrogen Dioksida (NO_2) dengan Menggunakan Metode Griess Saltzman*. Jakarta (ID): Dewan Standardisasi Indonesia.

[6] [BSN] Badan Standardisasi Nasional. 2005b. SNI 19-7119.7-2016. Cara Uji Kadar SO_2 dengan Metode Pararosanilin. Jakarta (ID): Dewan Standardisasi Indonesia.

[7] The Ministry of Environment and Forestry, Indonesia. 2018. Index of The Indonesian Environmental Quality (In Indonesian). Jakarta. Indonesia.

[8] Gebeyehu G, Soromessa T, Bekele T, Teketay D. 2019. Plant diversity and communities along with environmental, harvesting, and grazing gradients in dry Afromontane forests of Awi Zone, northwestern Ethiopia. *Journal of Taiwania*. Vol 64(3): 307-320.

[9] Sirait AM. 2001. Analisia Varians (ANOVA) dalam penelitian kesehatan. *Penelitian dan Pengembangan Kesehatan*. Vol 11(2): 39-43.

[10] Xiao R, Liu Y, Fei X, Yu W, Zhang Z, Meng Q. 2019. Ecosystem health assessment: A comprehensive and detailed analysis of the case study in a coastal

metropolitan region, eastern China. *Journal of Ecological Indicators.* Vol 98: 363-376.

[11] Berrios F, Campbell DE, Ortiz M. 2018. Energy-based indicators for evaluating ecosystem health: A case study of three benthic ecosystem networks influenced by coastal upwelling in Northern Chile (SE Pacific Coast). *Journal of Ecological Indicators*. Vol 95: 379-393.

[12] Radeva K, Velizarova E, Dancheva A. 2019. Land cover monitoring as part of a survey on wetland ecosystem conservation in the Negovan Village area using remote sensing tools. *Bulletin of the Faculty of Forestry*. (119): 175-188.

[13] Flint N, Rolfe J, Jones CE, Sellens C, Johnston ND, Ukkola L. 2017. An Ecosystem Health Index for a large and variable river basin: Methodology challenges a continuous improvement in Queensland's Fitzroy Basin. *Journal of Ecological Indicators*. Vol 626-636.

[14] Fairburn J, Schüle SA, Dreger S, Hil LK, Bolte G. 2019. Social inequalities in exposure to ambient air pollution: A systematic review in the WHO European Region. *International Journal of Environmental Research and Public Health*. Vol 16(17): 1-19.

[15] Balmes JR, Arjomandi M, Bromberg PA, Constantini MG, Dagincourt N, Hazucha MJ, Hollenbeck-Pringle D, Rich DQ, Stark P, Frampton MW. 2019. Ozone effects on blood biomarkers of systemic inflammation, oxidative stress, endothelial function, and thrombosis: The Multicenter Ozone Study in Older Subjects (MOSES). *PLoS ONE*. Vol 14(9): 1-22

[16] Asturi and Kusumawardani. 2017. *Analisis pencemaran udara dengan* box model *(daya tamping beban pencemar udara) studi kasus di Kota Tangerang. Jurnal Neo Teknika*. Vol 3(1): 21-28.

[17] Juniati H dan Dwitasari R. 2015. Pengembangan angkutan *shuttle* destinasi wisata di Kabupaten Gunung Kidul. *Jurnal Penelitian Transportasi Multimedia.* Vol 1(3): 1467-158.

[18] Ali W, Nafees M, Turab SA, Khan YM, Rehman K. 2019. Drinking water quality assessment using water quality index and geostatistical techniques, Marolan District, Khyber-Pakhtunkhwa, Pakistan. *Journal of Himalayan Earth Sciences*. Vol 52(1): 65-85.

[19] Ding J, Jiang Y, Fu L, Liu Q, Peng Q, Kang M. 2015. Impacts of land use on surface water quality in a subtropical river basin: A case study of the Dongjiang River Basin, Southeastern China. *Water 2015*. Vol 7: 4427-4445.

[20] Dawud M, Namara I, Chayati N, Muhammad F. 2016. Analisis sistem pengendalian pencemaran air Sungai Cisadane, Kota Tangerang berbasis masyarakat. *Seminar Nasional Sains dan Teknologi* 2016. 8 November 2016. Jakarta (ID): Fakultas Teknik Universitas Muhammadiyah Jakarta.

[21] Siddiqui E, Pandey J, Pandey U. 2019. The N:P:Si stoichiometry as a predictor of ecosystem health: A watershed-scale study with Ganga River, India. *International Journal of River Basin Management.* Vol 17(2): 199-207.

[22] Gyamfi-Ampadu E, Gebreslasie M, Mendoza-Ponce A. 2020. Mapping natural forest cover using satellite imagery of Nkandla Forest Reserve, KwaZulu-Natal, South Africa. *Remote Sensing Applications: Society and Environment*. Vol 18.

[23] Canetti A, Garrastazu MC, de Mattos PP, Bra EM, Pellico Netto S. 2018. Understanding multi-temporal urban forest cover using high-resolution images. *Urban Forestry & Urban Greening*. Vol 29: 106-112.

[24] Paul LA *et al*. 2020. Urban green space and the risks of dementia and stroke. *Environmental Research*. 109520.

[25] Soekmana O. 2009. Model pengembangan lingkungan kota ekowisata (studi di wilayah Kota Batu). *Humanity*. Vol 5(1): 42-47.

[26] Swedan N. 2019. Deforestation and land farming as regulators of population size and climate. *Acta Ecologica Sinica*.

[27] Isbell F, Craven D, Connolly J, Loreau M, Schmid B, Beierkuhnlein C, Bezemer TM, Bonin C, Bruelheide H, de Luca E *et al.* 2015. Biodiversity increases the resistance of ecosystem productivity to climate extremes. *Journal of Nature*. Vol 526(7574): 574-577.

[28] Douglas I. 2012. Urban ecology and urban ecosystem: Understanding the links to human health and well-being. *Current Opinion in Environmental Sustainability*: Vol 4(4): 385-392.

[29] Eriksson BK, Hillebrand H. 2019. Rapid reorganization of global biodiversity. *Journal of Science (New York, NY)*. Vol 366(6463): 308-309.

[30] Aminullah Y, Mahmudati N, Zaenab S. 2015. *Keanekaragaman makrofauna tanah daerah pertanian apel semi organik dan pertanian apel non organik Kecamatan Bumiaji, Kota Batu sebagai bahan ajar biologi SMA*. *Jurnal Pendidikan Biologi Indonesia*. Vol 1(2): 178-187.

[31] Wells NM, Donofrio GA. 2016. *Urban Planning, the Natural Environment and Public Health (2nd Edition).* In: Jerome ON. *Encyclopedia of Environmental Health.* Vol 5. Page: 565-575. Burlington (US): Elsevier.

[32] Hoogendijk EO, van der Noordt M, Onwuteaka-Philipsen BD, Deeg DJH, Huisman M, Enroth L, Jylhä M. 2019. Sex differences in healthy life expectancy among nonagenarians: A multistate survival model using data from the Vitality 90+ study. *Exp Gerontol*.

[33] Wahyuningsih CS, Trisnowwati H, Fitriani A. 2016. Hubungan paparan asap rokok dalam rumah dann usia ibu bersalin dengan berat bayi lair di RSUD Wonosari, Kabupaten Gunung Kidul. *Jurnal Formil (Forum Ilmiah) KesMasRespati.* Vol 1(2): 121-129.

[34] Azege M, Motbainor A, Nigati D. 2020. Exploring geographical variations and inequalities in access to improved water and sanitation in Ethiopia: Mapping and spatial analysis. *Heliyon*. Vol 6(4): Article e03828.

[35] Marpaung JL, Sutrisno A, Lumintang R. 2017. *Penerapan metode anova untuk analisis sifat mekanik komposit serabut kelapa*. *Jurnal Online Poros Teknik Mesin*. Vol 6(2): 151-162.