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RESEARCH PAPER

Carbon emission from biodiversity research conferences in Indonesia

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Abstract. Participants in scientific conferences have been traveling to the cities of conference venues. These mobilizations left carbon footprints due to carbon dioxide (CO_2) emissions generated from the scientists' transportation to their conference venue. This study looks at the carbon footprint of scientists who attended scientific biodiversity conferences in Indonesia from 2015 to 2019. We have identified that 30 scientific biodiversity conferences were conducted in 17 cities on five different islands during the corresponding period. The conferences have published 3092 scientific articles written by 9617 authors from various disciplines. The estimated carbon emission due to those scientists' transportation was 622 tons CO_2-eq. This emission figure is almost equivalent to the emission produced by a person circling the earth 91 times using a passenger aircraft. A new paradigm of virtual conference should be considered to minimize the carbon footprint resulted from the scientists' transportation to and from the conference venue. Thus, the CO_2-eq emissions released by scientists' transport can be reduced significantly. These emission reductions may mitigate and minimize the magnitude and impact of climate change to some extent.

Keywords: biodiversity conference; carbon emission; climate change; scientists; transportation

1. Introduction

Climate change has been considered a severe threat to the survival of life on earth (Hansen et al., 2012; Scholze et al., 2006; Wheeler & Von Braun, 2013). One of the leading causes of climate change is the increase in greenhouse gases (GHG) emissions due to anthropogenic activities (Montzka et al., 2011). One of the significant GHG emissions that are contributing to climate change is carbon dioxide (CO_2). The Intergovernmental Panel on Climate Change (IPCC) has identified fossil fuel as the cause of the global increase of CO_2 (IPCC, 2014). Furthermore, IPCC has reported that the use of fossil fuels contributed almost 65% (c.a. 32 Gt carbon dioxide equivalent or CO_2-eq) of the total GHG emitted in 2010 worldwide (c.a. 49 Gt CO_2-eq). The CO_2 emissions generated from the transportation sector are estimated to be 7 Gt CO_2-eq. Thus, emissions from the transportation sector have become a particular concern for policymakers in various countries, especially in the provision of mass transportation or electricity-based transportation, which is expected to minimize CO_2 emissions from this sector (Fulton et al., 2017).

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The transportation sector is one of the drivers of economic growth in a country (Deng, 2013). It also plays an essential role in the development and dissemination of science and technology. Transportation contributes to the scientific meeting in terms of dissemination (Hamant et al., 2019; Spinellis & Louridas, 2013). According to the Oxford Learner's Dictionaries, a conference is defined as "a large official meeting, usually lasting for a few days, at which people with the same work or interests come together to discuss their views". The majority of conference participants are not from the city where the conference is being held. Instead, many of them travel from outside the city, hundreds of kilometres away from the conference venue. Therefore, participants who travel to the conference by car, aeroplane, or other transportation modes will leave a carbon footprint.

The numerous scientific biodiversity conferences hosted in Indonesia are considered as a consequence of the country's status as a mega biodiversity country. Indonesia is a biodiversity hotspot, making it a paradise for biological research (Barber et al., 2014; Brearley et al., 2019; Riswan & Yamada, 2006). The study is supported by a large number of researchers from various universities and research institutions. Therefore, it is not surprising that many biodiversity conferences were conducted in Indonesia to support biodiversity research dissemination in this country.

Scientists have a quandary when it comes to the importance of attending scientific conferences. Scientific conferences are needed to disseminate research results and to build scientific networks (Rowley-Jolivet, 1999). The conferences, on the other hand, have negative implications. One of the adverse effects is carbon emissions, mainly due to transportation for the scientist's mobilization to the conference venue (Achten et al., 2013), which have been globally discussed (Hamant et al., 2019; Nathans & Sterling, 2016; Rosen, 2017; Spinellis & Louridas, 2013). Data availability on carbon emissions resulted from the scientific biodiversity conference in Indonesia is still lacking. Even though the number of scientific publications about Indonesian biodiversity is exponentially increasing (Amelia & Rahmaida, 2017). There is a lack of information on the total amount of published proceedings, conducted biodiversity conferences and the estimation of carbon footprint produced from these biodiversity theme conferences. The analysis of carbon emission produced from scientific seminars is essential for two reasons. Firstly, it will support information disclosure due to climate change mitigation policy (Spinellis & Louridas, 2013). Secondly, scientific communities have an ethical responsibility to implement their scientific belief in climate change issues and lead the way to provide an example of minimizing carbon emission (Hamant et al., 2019). Therefore, this paper aims to estimate and discuss the carbon emissions of the scientific biodiversity conferences that were held in Indonesia from 2015 to 2019. This paper is expected to provide and increase the understanding of the importance of virtual conferences, which are currently held globally due to the COVID-19 outbreak (Porpiglia et al., 2020; Wiederhold, 2020).

2. Methods

2.1. Data extraction

The investigated conferences in this study were scientific conferences on the theme of biodiversity and held in Indonesia by an organization that regularly organized scientific conferences from 2015 to 2019. The source of data is the published proceedings of those investigated conferences. Data extracted from the proceedings include the conference date, the venue's location, the conference topic, the paper's subject, the author of the article, the origin of the author's institutions, and the author's address. If the author is more than one, the extracted author's institution and addresses are the contributing or the main author. In addition, in several proceedings that were published within 2015-2019, we found international level conferences. However, since we aim to analyze the carbon footprint of scientific conferences in Indonesia, we included all of these national and international conferences in this study.

2.2. Carbon footprint assumptions

The calculation of the carbon footprint in this study is based on several assumptions. First, the calculated carbon footprint is the carbon footprint that comes only from the participants' transportation and does not include the carbon footprint from other components such as the electricity or the use of internet access during the conference, and so on. Second, the modes of transportation were limited to buses and planes only. Third, the round-trip distance travelled is set to be 20 km and 30 km, by bus for the distance travelled within the city and the distance travelled to the nearest airport, respectively. Fourth, participants from the same city as the conference venue were treated as though they were traveling within the city. Fifth, we defined aircraft distance as the distance between the nearest airport of the main author's address and the closest airport to the city where the conference was held. The aircraft distance calculation was conducted by using the distance calculation through Google Maps (maps.google.com). Lastly, we used the average carbon dioxide equivalent (CO_2-eq) emission as reported by the IPCC, i.e. the emission per passenger for buses and aircraft is 80 and 170 g CO_2-eq km^{-1}, respectively (Sims et al., 2014).

2.3. Data analysis

The calculation of CO_2-eq emission for each paper published in the proceedings (E, in g) is done by multiplying the distance traveled by the speaker (d, in km) with the average value of CO_2-eq emissions factor (EF, in g CO_2-eq km^{-1}) for each mode of transportation used per passenger. The formula used is as follows:

$$E = d * EF \quad (1)$$

The minimum total estimate of CO_2-eq emissions for each scientific conference (tE, in Mg CO_2-eq) was found by summing up the calculated CO_2-eq emissions of all papers disseminated in a conference. The formula is as follows:

$$tE = \sum E * 10^{-6} \quad (2)$$

To determine the factors that influence CO_2-eq emissions (Y_E), we performed a simple linear regression model using three predictor variables, i.e., the number of articles (X_A), the number of origin cities of the participants (X_C), and the total number of participants involved (X_P). Therefore, the formula is as follows:

$$Y_E = X_A + X_C + X_P \quad (3)$$

Since the data distribution of the used three variables were not normally distributed, we performed logarithmic transformations to those variables. All calculations and visualization were done using open-source R software (R Core Team, 2020) by utilizing the RStudio platform (RStudio Team, 2020).

3. Results and discussion

3.1. Results

Scientific conferences on biodiversity have been held 30 times on five islands in Indonesia during 2015-2019 (Table 1). In total, 3092 papers were presented and written by 9617 authors. Of these, 1854 articles discussed plant taxa, followed by animal taxa (949 articles), and articles that did not discuss those taxa but were relevant to biodiversity or life science (289 articles). Of the 3092 articles, 65% were written by university-affiliated authors, research and development affiliated authors wrote 26%, and 9% were written as collaborations between universities and research and development affiliated institutions.

Table 1. The general information on the biodiversity conference held in Indonesia from 2015 to 2019.

Island	Number of the conference	Number of the cities of the venue	Taxa			Number of the authors involved	Number of the papers based on affiliated institutions			Number of the origin city of the author
			Flora	Fauna	Others		University	R&D	Collaboration	
Bali	1	1	87	66	8	556	115	30	16	44
Borneo	5	4	312	150	67	1802	446	48	35	58
Java	20	8	1277	629	174	6232	1188	701	191	91
Sulawesi	2	2	43	29	10	275	55	17	10	24
Sumatra	2	2	135	75	30	752	189	22	29	38
Total	30	17	1854	949	289	9617	1993	818	281	122

Table 2. The estimated total value of CO_2-eq emissions by the city where the conference was held in the 2015-2019 period.

City of the conference	Year of the conference	Number of the city of origin of the participant	Number of papers	Number of the authors	CO_2-eq emissions by bus (Mg)	CO_2-eq emissions by plane (Mg)	CO_2-eq emissions (Mg)
Balikpapan	2016	30	147	463	1.58	39.15	40.73
Bandung	2015, 2016, 2017, 2018	52	596	1835	4.93	79.19	84.12
Berau	2017	24	69	227	0.20	23.17	23.37
Bogor	2016, 2017, 2018	55	539	1592	3.44	80.25	83.69
Denpasar	2017	44	161	556	1.76	79.00	80.76
Depok	2017	19	45	145	0.20	18.93	19.13
Gorontalo	2016	18	44	120	0.55	14.74	15.29
Jakarta	2015	14	70	180	0.66	4.15	4.80
Magelang	2019	10	54	174	0.38	5.28	5.66
Medan	2017	25	123	422	0.68	26.98	27.66
Padang	2016	21	117	330	1.47	13.92	15.40
Palu	2017	14	38	155	0.08	10.92	10.99
Pontianak	2016, 2017	39	200	759	0.52	42.46	42.98
Samarinda	2016	16	113	353	2.12	13.34	15.46
Semarang	2015	13	45	121	1.82	2.04	3.86
Surakarta	2016, 2018	51	357	1154	1.70	70.06	71.75
Yogyakarta	2015, 2016, 2017	48	374	1031	2.36	74.07	76.43
Total		122	3092	9617	24.43	597.66	622.09

CO_2-eq emissions from 2015 to 2019 were estimated at 622 Mg (Table 2) or equivalent to 201 kg of CO_2-eq emissions for each paper presented either orally or in a poster. CO_2-eq emissions from air travel (598 Mg CO_2-eq) were significantly higher for those who traveled by bus (24 Mg CO_2-eq). On average, the highest amount of CO_2-eq emissions was from the conference held in

Denpasar (Bali), reaching 502 kg CO_2-eq for each paper presented (Figure 1). Meanwhile, the conference in Semarang (Java) had the lowest emission with 86 kg CO_2-eq for each article presented.

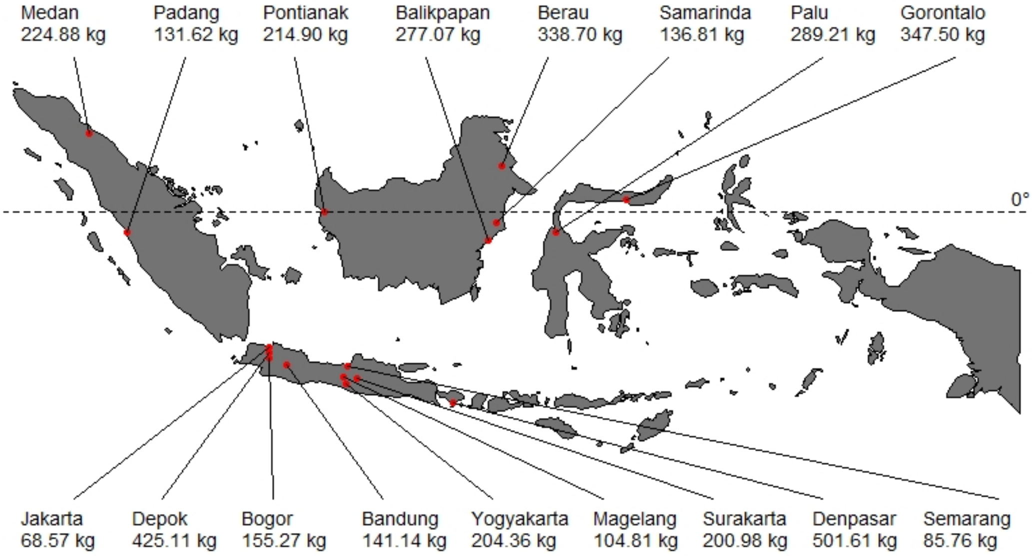

Figure 1. The average value of CO_2-eq emissions (kg) for each article presented in each venue city of scientific conferences on Indonesia's biodiversity during the 2015-2019 period.

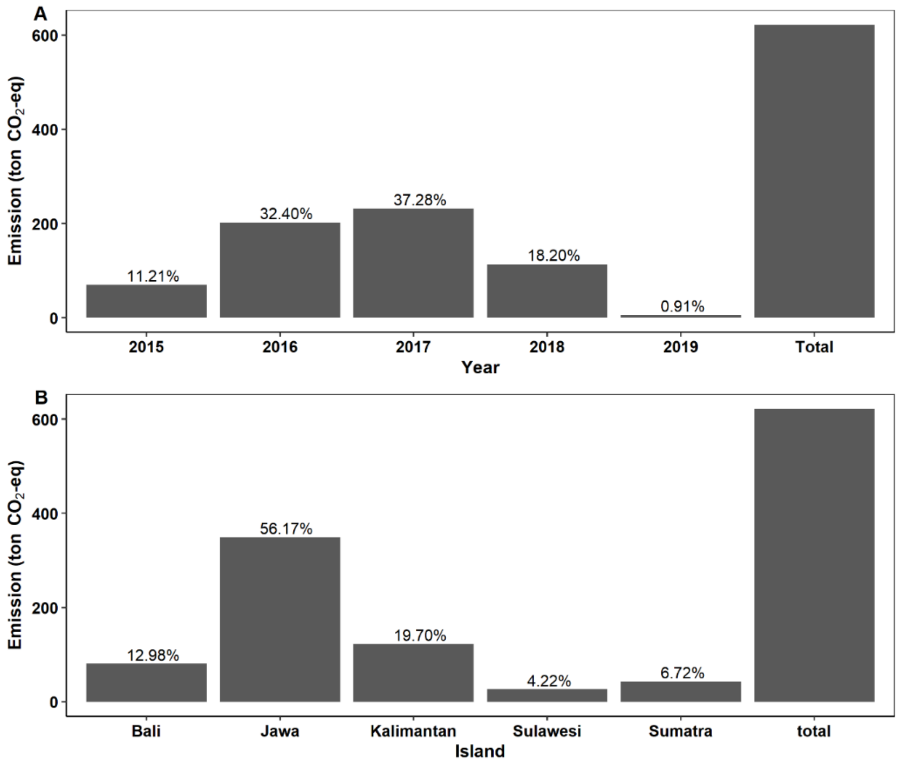

Figure 2. The annual value of CO_2-eq emissions by year (A) and island (B) in the 2015-2019 period. The percentages above each bar chart show the contribution of each year CO_2-eq emissions to five years CO_2-eq total emissions

The number of CO_2-eq emissions from conferences peaked in 2017 (344 Mg CO_2-eq, Figure 2A). During the 2015-2017 period, CO_2-eq emissions increased significantly from 11% (2015) to 37% (2017). Meanwhile, from 2017-2019, there was a significant decrease from 37% (2017) to only 1% (2019). In concordance with the number of papers and the participant cities of origin (Table 1), Java Island was the highest contributor to the CO_2-eq emissions during 2015-2019, reaching 56% of CO_2-eq emissions (349 Mg CO_2-eq, Figure 2B). Despite having the greatest emissions for each paper presented (Table 2), Denpasar (Bali) only contributes 13% of total emissions.

The number of authors' cities of origin and the number of papers disseminated significantly affected the average CO_2-eq emissions per article (Table 3, Adj. R2 = 76.76%, p <0.001). However, the number of involved authors did not significantly affect CO_2-eq emissions for each paper published in the proceedings.

Table 3. The results of the linear model to predict CO_2-eq emissions.

Variable	Estimate (β)	Standard error (SE)	t-value	Pr(>|t|)
Intercept	3.11	0.74	4.19	0.001
log(city of origin)	1.80	0.30	6.11	3.7e-05
log(number of paper)	-2.21	0.55	-4.00	0.001
log(number of the author)	1.18	0.58	2.02	0.065

3.2. Discussion

This research aims to provide an overview of the value of CO_2-eq emissions caused by the scientific biodiversity conferences. The results showed that the predicted amount of CO_2-eq emissions for five years (2015-2019) reached 622 Mg of CO_2-eq emissions, indicating that attending a scientific conference contributes to CO_2-eq emissions. The calculated emission value is equivalent to the average emission per passenger produced by a regular aeroplane when circling the earth 91 times.

The results showed an increase in CO_2-eq emissions from 2015-2017, then decreased significantly from 2017-2019 (Figure 2A). The increase in 2015-2017 was due to the increasing number of scientific seminars in 2015, 2016, and 2017 that reaches 4, 9 and 9 times, respectively. Then this number decreased to 7 and 1 times in 2018 and 2019, respectively. The significant decrease in the number of scientific conferences from 2017-2019 is probably due to local and national political events that were happening in 2018 and 2019 (Badrun, 2018; Solihah, 2018). In those years, two critical national agendas were carried out, i.e., the governor and the mayor elections in 171 regions (2018) and legislative and presidential elections (2019); therefore, the activities involving large numbers of people, such as scientific conferences, were limited and avoided.

This study also indicated that the highest CO_2-eq emissions came from scientific conferences held in Java (Figure 2B). These results are directly proportional to the number of scientific conferences in Java (20 times), Kalimantan (5 times), Sulawesi and Sumatra (2 times each), and Bali (1 time). Also, the conferences held in Java have the largest number of cities of origin. These results are in line with the linear model results, which shows that the number of the city of origin of the participants has a significant effect on CO_2-eq emissions (Table 3). The highest carbon emissions from a scientific conference that was held on Java Island which is not surprising. With all the facilities, Java Island has become the centre of economy and politics, including science and technology (Firman et al., 2007; Kusharjanto & Kim, 2011). Furthermore, many universities or research institutions are located on Java Island. Those factors, of course, resulted in many activities that have been done in Java, including scientific conferences.

3.2.1. Minimizing carbon footprint due to scientific conferences

Our results suggest that the number of the city of participants positively affects the average emission of CO_2-eq emissions for each article (Table 3). Therefore, scientific conferences are recommended to involve as few participants outside the city as possible, especially those cities where the participants need to use long-distance air travel to the conference location. However, to reach a broad range of participants from various cities, more conferences could be held in Indonesia's different cities. If we consider the goal of scientific conferences, minimizing the number of cities of origin of participants and maximizing the number of articles will support scientific dissemination objectives while establishing less scientific networks. This unsuccessful network formation and development will occur because the participants are confined to only involve a small scientific community. Thus, if scientific conferences are held traditionally (face-to-face meetings), from a carbon footprint perspective, there will be a trade-off between minimizing the carbon footprint (CO_2 emissions) and maximizing scientific formation and community networks development.

We also found that the CO_2 emissions were mainly due to air travel (598 Mg CO_2-eq) compared to ground transportation (24 Mg CO_2-eq) (Table 2). The results indicate that scientists should consider other alternatives and reduce their reliance on air travel to attend the conference (Nathans & Sterling, 2016). Even though the Indonesian government, for example, has a roadmap to decrease the carbon footprint caused by air transportation through the use of biofuel or aircraft regeneration, they still emit a significant amoun of carbon and alternatives should be implemented to minimize the carbon footprint from air travel. Options to organize scientific conferences that can minimize carbon footprint include (1) the implementation of online (virtual) scientific conferences or (2) mixing between virtual conferences and traditional conferences. Those who came from the same city as the conference venue could attend the meeting physically. However, virtual meeting participation is compulsory for participants from outside the city who should travel using long-distance air travel. Virtual scientific conferences can potentially reduce carbon footprint because this type of conference does not require a venue (seminar venue, accommodation, and supporting facilities), and there is no use of transportation modes by the participants to and from the venue of the scientific conference. The potential drawback of this virtual scientific seminar is in the networking aspect of the scientific community. The type of communication, lobbying activities and discussion preferences of each scientific community member may differ individually and do not necessarily fit into the virtual communication model. However, to minimize these potential weaknesses, some simple rules can be applied in conducting virtual seminars, as Fadlelmola et al. (2019) have discussed.

3.2.2. The COVID-19 Pandemic for Carbon Emissions due to Scientific Conferences

The COVID-19 outbreak has resulted in changing meeting patterns from physical to virtual meetings (Wiederhold, 2020). These changes have positively affected the environment (Eroğlu, 2020; Zambrano-Monserrate et al., 2020), for example, by significantly decreasing daily carbon emissions globally, especially those resulting from transportation modes and energy consumption (Le Quéré et al., 2020). Changes in the pattern of meetings also occurred in the scientific conferences, which have turned into virtual meetings (Porpiglia et al., 2020). Apparently, this virtual scientific meeting had been proposed long before the COVID-19 pandemic hit (Dolci et al., 2011; Reay, 2003). Virtual scientific meetings have also become a new and successful method in disseminating science and technology (Fadlelmola et al., 2019). Furthermore, the implementation of virtual meetings can reduce CO_2-eq emissions by minimizing transportation modes by participants, which are the primary source of carbon emissions (Hamant et al., 2019). However, virtual meetings also produce carbon emissions due to internet access (Baliga et al., 2009). Therefore, further research on estimating the emitted carbon from internet use related to virtual conferences needs to be done.

4. Conclusion

During the 2015-2019 period, Indonesia's scientific biodiversity conferences have been held at least 30 times in 17 cities. A total of 3092 papers that involved 9617 authors were presented at those conferences. However, although many articles have been disseminated in science and technology development, the scientific conference has produced at least 622 Mg of CO_2-eq emission, which only came from participants' transportation to and from the conference venues. Therefore, changing the meeting type to the virtual conference or mixing between traditional and virtual meetings can significantly reduce CO_2 emissions due to the absence of transportation modes.

Author's contribution

Both authors have an equal contribution to this work as the main contributor. In addition, both authors have equal works on conception, planning, execution, data mining, writing, interpretation, and data analysis.

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