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Evaluation of Flood and Drought Events Using AR5 Climate Change Scenarios in Indonesia

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ABSTRACT Indonesia is an archipelagic country located on the equator. The issue of climate change has become a global issue that has impacted several sectors in Indonesia recently. The presence of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has contributed to conducting studies on flood and drought events. This review paper summarized 16 published papers that have gone through peer-review, both in the form of publications in journals and at conferences. Since the release of the IPCC AR5 to date, ten studies on flooding and six studies on drought events have been conducted. The most publications on this in 2019 were five publications. Of the various types of the Representative Concentration Pathway (RCP) scenarios used with various methods, the most widely used scenario RCPs is RCP4.5. From the climate change scenario, precipitations parameter is the main parameter that is used in assessing flood or drought events. There are studies conducted on a district / city, provincial scale, and some are even carried out on a watershed scale. The location or province that most flood studies have been carried out is in the capital of Jakarta. The results of these studies generally indicate that the incidence of floods and droughts will increase in the future. Therefore, adaptation steps are needed to deal with unfavorable conditions in the future. Moreover, as the capital city, Jakarta has been estimated that the projected flood incidence will increase. Several publications have provided steps to deal with these challenges on the positive side.

KEYWORDS Climate Change; AR5; IPCC; Flood; Drought.

1 INTRODUCTION

Climate change has transformed or increased the frequency of flood and drought due to more frequent and severe weather conditions (Yang et al., 2012). This shows that the extremity of these phenomena extensively affects the economic and ecological sectors (Lehner et al., 2006; Marengo and Espinoza, 2016). They are also observed to influence the quantity and quality of water resources (Hrdinka et al., 2012). In addition, flood and drought are harmful to agricultural areas (Rau et al., 2021) and crop production, which impends food security (Pratiwi et al., 2020). These phenomena have similar economic impacts on communities (De Silva and Kawasaki, 2018), such as the heavy losses of housing areas, agricultural land, and other properties (Khan et al., 2011). Low-income households are also more vulnerable to the financial losses caused by flood and drought, due to their heavy reliance on natural resources (De Silva and Kawasaki, 2018). Furthermore, the effects of the ecosystem are directly similar to the frequency and magnitude of flooding and drought (Parasiewicz et al., 2019). Although land-use change effects are highly evaluated (Utamahadi et al., 2018), extreme weather and climate events still have profound significant implications for species and ecosystem management (Maxwell et al., 2019). This indicates an urgent need to understand several aspects of the ecological response to extreme events (Ledger and Milner, 2015).

Although climate change alters water distribution in space and time, the quantification of drought risk is still uncertain under global warming (Naumann et al., 2021). This shows that climate change is expected to futuristically increase extreme events, as well as the potentially damaging effects on river structures and infrastructures, such as bridges (Rau et al., 2021, 2016; Leigh et al., 2015). Since Indonesia has many rivers, special awareness is needed regarding the present climate change conditions. As an archipelagic country, it also has about 60% population residing in coastal areas, where community developments primarily increase the risk of disasters through flood, drought, and rob flood (Rudiarto et al., 2018). From January 1 to December 31, 2021, flood disasters were highly dominant in almost all parts of Indonesia at 1794 events. The country also reportedly experienced 15 drought in the same year. This condition prompted an increase in the number of reports emphasizing the impact of climate change on flood and drought (Ariansyah, 2022). Therefore, this study aims to evaluate flood and drought events in Indonesia, using AR5 climate change scenarios.

2 CLIMATE CHANGE SCENARIO

Based on the increasing concerns about manmade global climate change, the United Nations IPCC (Intergovernmental Panel on Climate Change) was established in 1988 (Bolin, 2007). This panel has reportedly produced six reports on climate change adaptation and mitigation. In 1990, the First IPCC Assessment Report (FAR) was published, with the UNFCCC (UN Framework Convention on Climate Change) also predated (Porter et al., 2017). Subsequently, the Second, Third, Fourth, and Fifth Assessment Report (SAR, TAR, AR4, and AR5) were established, with the AR6 recently launched in 2022.

The utilization of this climate change scenario product has reportedly been carried out by various experts in several Indonesian locations, as shown in Table 1. However, only the utilization of the IPCC's AR5 scenarios is emphasized in this present report. In 2013-2014, the IPCC launched the Fifth Assessment Report (AR5), which contains four available Representative Concentration Pathway (RCP), namely RCP8.5, RCP6, RCP4.5, and RCP2.6/RCP3 -PD (The numbers = the forcings for each RCP; PD = Peak and Decline) (Wayne, 2014). These pathways emphasize the range of radiative forcing values, with approximately 2100 found in the open literature, i.e., from 2.6 to 8.5 Wm^{-2} (Van Vuuren et al., 2011). RCP8.5 assumes minimal effort to reduce emissions and is a failure to curb warming by 2100. After achieving 2100, RCP6.0 is known to stabilize total radiation exposure through various technologies and strategies, to reduce greenhouse gas emissions. With RCP4.5 similar to the lowest emission scenario (B1) assessed in AR4, RCP2.6 is observed as the most ambitious pathway used in solving climate change (Jubb et al., 2013).

Before a regional scale usage, these RCP scenarios are often downscaled using GCM or tools such as MRI-CGCM 3.2, CMIP3, NHRCM, CMIP5, (MRI-AGCM) 3.2S, GFDL-ESM2M, GISS-E2-R, CMIP5 GCM, GFDL-ESM2M, GISS-E2-R, CCAM, etc. The detailed use of the model and RCP scenarios for each study is shown in Table 1.

In Indonesia, several experts have also used various RCP scenarios to analyze flood and drought. These reports are then used to support AR5 IPCC, which was launched in 2014. In this context, a total of 16 reviews on flood and drought were subsequently observed regarding several publications in journals and conference papers, which had undergone a peer review process. Based on Figure 1, the comparative analysis of RCP utilization was much higher for flood reports than drought. This indicated ten and six reports for flood and drought, respectively, as shown in Table 1 and Figure 2. In this case, the highest use of the RCP scenario was observed in 2019, with four and one publication for flood and drought, respectively.

Figure 2 showed the distribution of RCP scenarios for the two experimental fields, where RCP4.5 was very highly utilized with the observation of 8 flood and 4 drought publications. The frequency of this scenario emphasized the good outputs of the downscaling data process for the targeted study area. In addition, the RCP4.5 scheme imposed strict mitigation measures, limiting the coercion

Table 1. Experimental studies of bricks containing EFB fibre

Study	Reference	Area Scale/Location	Study Focus	GCM/Tool (Scenario)	Parameters Utilized
1	Emam et al. (2016)	Ciliwung River, Jakarta, Indonesia	Flood	MRI-CGCM 3.2 (RCP4.5)	Precipitation
2	Yamamoto et al. (2021)	Batanghari River Watershed, Jambi Province, Indonesia	Flood	CMIP3 tool and NHRCM (RCP8.5)	Sea Surface Temperature (SST)
3	Iwami et al. (2017)	Solo, Pampanga, Chao Phraya, Mekong, and Indus River Watershed, Indonesia	Flood	CMIP5 tool and MRI-AGCM 3.2S (RCP8.5)	Precipitation
4	Barkey et al. (2019b)	Bantimurung Bulusaraung National Park, South Sulawesi Province, Indonesia	Flood	GFDL-ESM2M and GISS-E2-R (RCP6.0 and RCP4.5)	Precipitation
5	Barkey et al. (2019a)	Bantimurung Bulusaraung National Park, South Sulawesi Province, Indonesia	Drought	CMIP5 GCM tool (RCP4.5 and RCP6.0 scenarios used the GFDL-ESM2M and the GISS-E2-R climate model, respectively)	Precipitation
6	Parkhurst et al. (2019)	Java, Bali and Nusa Tenggara, Indonesia	Drought	Unmentioned model (RCP8.5 and RCP4.5)	Precipitation
7	Pratiwi et al. (2018)	Cirebon Regency, Indonesia	Drought	Unmentioned model (RCP4.5)	Precipitation
8	Nurlatifah et al. (2019)	Cilacap, Indonesia	Drought	CCAM (RCP4.5)	Precipitation

Study	Reference	Area Scale/Location	Study Focus	GCM/Tool (Scenario)	Parameters Utilized
9	Kefi et al. (2020)	The Pasig–Marikina–San Juan River in Metro Manila, Philippines, and Ciliwung River in Jakarta, Indonesia	Flood	MRI-CGCM3 MIROC5 HadGEM2-ES (RCP4.5)	Precipitation
10	Levina and Hatmoko (2019)	Bodri-Juwero, Notog, and Wlingi Irrigation Weirs, Indonesia	Drought	CNRM CM5, CNRM RCA, CNRM v2 RegCM, CSIRO MK3,6, EC EARTH, GFDL ESM, and IPSL (RCP8.5)	Precipitation
11	Daksiya et al. (2021)	Jakarta, Indonesia	Flood	CMIP5 Tool and NEX-GDDP (RCP8.5 and RCP4.5)	Precipitation
12	Kazama et al. (2020)	Ciliwung River Watershed, Indonesia	Flood	CNRM- CM5, IPSL-CM5A-LR, GFDL-ESM2M, MPI-ESM-LR, MIROC-ESM-CHEM, CanESM2, CSIRO-Mk3-6-0, HadGEM2- AO (RCP8.5, RCP4.5, and RCP2.6)	Precipitation
13	Farahnaz et al. (2020)	Barito Watershed, Indonesia	Drought	CMIP5 tool for NEX-GDDP (RCP6.0)	Temperature and Precipitation
14	Budiyono et al. (2015)	Jakarta, Indonesia	Flood	GFDL-ESM2M, HadGEM2-ES, IPSL- CM5A-LR, MIROC-ESM-CHEM, and NorESM1-M (RCP8.5, RCP6.0, RCP4.5, and RCP2.6)	Precipitation
15	Januriyadi et al. (2020)	Jakarta, Indonesia	Flood	CNRM CM5, IPSL-CM5A-LR, GFDL-ESM2M, MPI-ESM-LR, MIROC-ESM-CHEM, CanESM2, CSIRO-Mk3-6-0, HadGEM2- AO (RCP8.5, RCP4.5, and RCP2.6)	Precipitation
16	Muis et al. (2015)	Indonesia	Flood	Unmentioned model (RCP8.5, RCP6.0, RCP4.5, and RCP2.6)	Precipitation

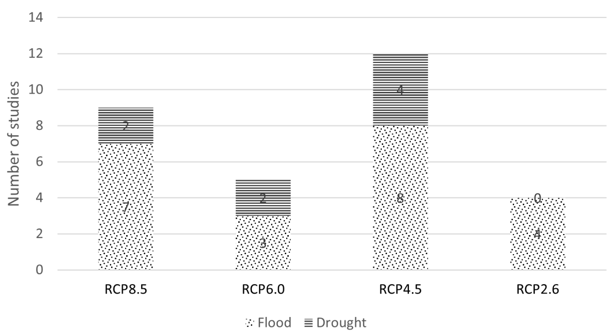

Figure 1. Trends in Use of IPCC AR5 Climate Change Scenarios

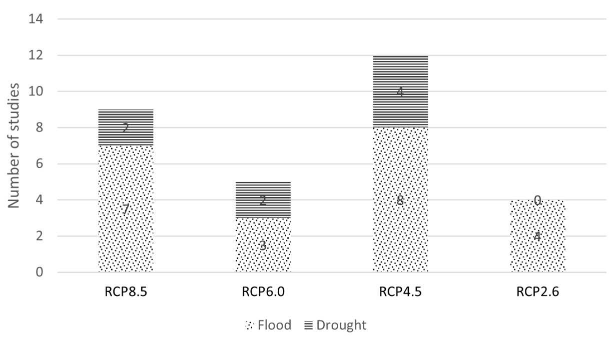

Figure 2. Comparison of Use of Types of RCP for Flood and Drought Studies

to approximately 4.5 Wm^{-2} (Tebaldi and Wehner, 2018). It also encompassed long-term greenhouse gas emissions, short-lived species, and land-cover use in the global economic framework (Thomson et al., 2011). Irrespective of these conditions, the use of the lowest scenario, RCP2.6, produced only four flood publications. This system represented the literature on mitigation scenarios, to limit the increase in global mean temperature to 2°C. Based on these descriptions, subsequent analysis is needed on the patterns by which the feasibility of achieving low concentrations depended on the technology and assumption of abatement potential (Van Vuuren et al., 2011).

In these previous reports, the utilized RCP varied according to the location and scale of the targeted experimental area. This showed that some analyses were carried out on a district/city, provincial, or watershed scale. The selection of these scales is also very dependent on each expert's target area. Meanwhile, the dominant utilized parameter was precipitation, which occurred in 14 publications. One publication also used two parameters in a single performance, namely precipitation and temperature. Irrespective of these conditions, another analysis used different parameters, namely the Sea Surface Temperature (SST). The selection of the number of utilized parameters also highly emphasized the method of calculating the potential for flooding and drought in each publication.

Precipitation is the main parameter in assessing the occurrence of these disasters, as the variability of rainfall often causes global flood and drought. This explains that climate change has a close relationship with rainfall patterns and temperature (Khan et al., 2021), where some related indices were observed, such as The precipitation concentration period (PCP), The standardized precipitation index (SPI), and The long-cycle drought–flood abrupt alternation index (LDFAI). From this condition, the use of multiple indices is often substituted for assessing flood and drought risk (Cai et al., 2020). This ensures the high usage of precipitation in these disasters' publications.

3 CLIMATE CHANGE CHALLENGES AND ADAPTATION TO FLOODS IN INDONESIA

Based on Figure 3, the distribution of the experimental locations is observed for projected flood events, using AR5 RCP scenarios. In this case, the study number emphasized the experimental performance locations (Table 1). The area scales utilized also included the provincial, watershed, island, and country scales. This indicated that the most utilized area for flood analysis was the capital city of Jakarta, which had a very high population density and is a flood-prone location. According to Kazama et al. (2020), the futuristic combination of land use, site subsidence, and climate change in this city is expected to produce five times the presently observed damages. This was in line with Emam et al. (2016), although only the RCP4.5 scenario was used. In this case, futuristic land use change is expected to increase by 130%, regarding the correspondence of the rainfall's peak flow to the 50-year return period in 2030. For Kefi et al. (2020), dangerous classifications are futuristically expected in Jakarta due to the 80% increase in flood damage, compared to the present scenario.

According to the RCP scenarios' predictions, several Indonesian analyses were subsequently conducted as references for handling flood events, toward the mitigation and solution of climate change. These analyses included (Januriyadi et al., 2020), where adaptation measures were carried

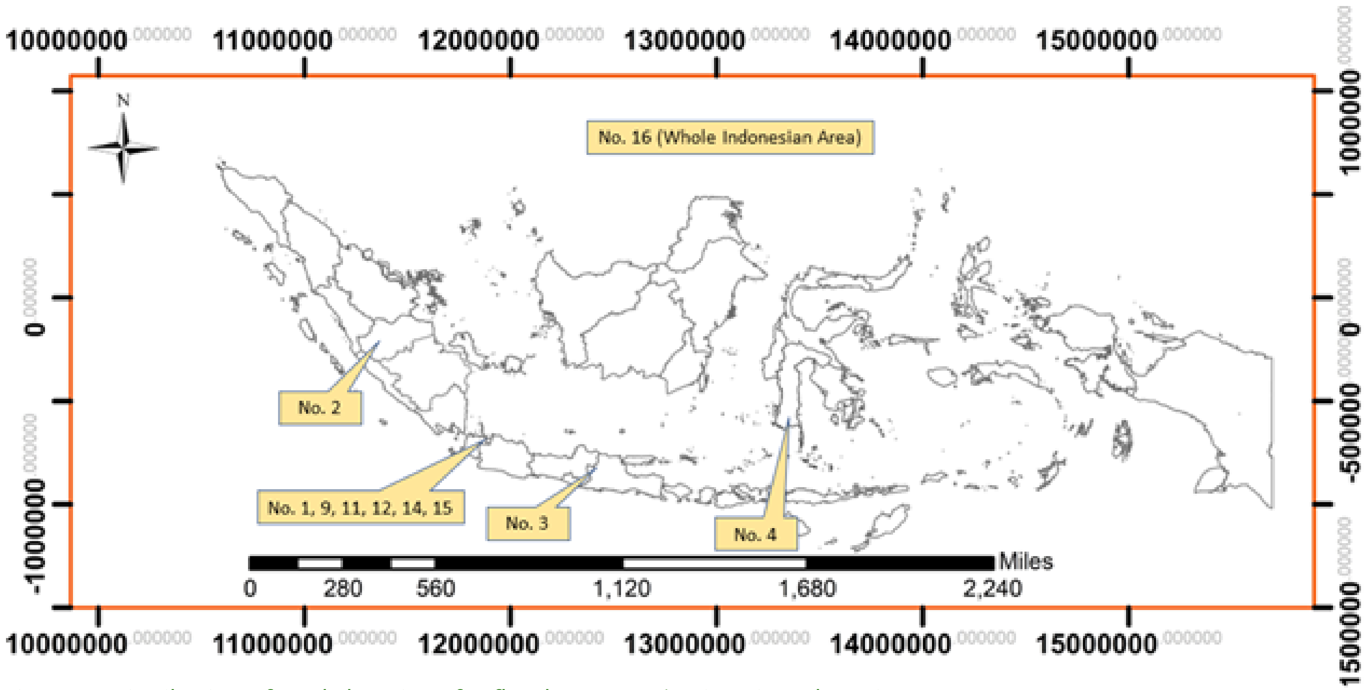

Figure 3. Distribution of study locations for flood event projections in Indonesia

out, including the structural and non-structural channels in Jakarta. This was because adaptation measures with ponds, dikes, and RP (retention ponds) had the potential to reduce the magnitude and uncertainty of flood risk (Januriyadi et al., 2020; Daksiya et al., 2021). Similar to Emam et al. (2016) and Budiyono et al. (2015), land and climate change were projected using scenarios RCP8.5, RCP6.0, RCP4.5, and RCP2.6, indicating a 12% reduction in risk with the occurrence of land use change through the official Jakarta Spatial Plan in 2030. However, a significant increase is expected to occur when future land use change is continuously observed at a similar rate as in the last 30 years.

Besides the use of AR5 products for flood events in Jakarta, several analyses were also carried out in various Indonesian locations. In this case, the utilized scale significantly varied from the watershed to the province, with some even using the entire scalar processes. According to Muis et al. (2015), a method was proposed to integrate recent advances in the global-scale modelling of flood hazards and land change. This enabled a probabilistic analysis of future trends in national-scale flood risk. Using a watershed scale, another analysis was also conducted in Batanghari River Watershed, Jambi Province (Yamamoto et al., 2021), where the impact of climate change was examined on flood inundation in Sumatra Island. This applied the rainfall data from the RCP8.5 scenario as input in the climate change factor. Other external analyses were also carried out in Solo and various Asian locations, such as in Pampanga, Chao Phraya, Mekong, and Indus River Watershed (Iwami et al., 2017). In addition, the use of RCP to project the impact of climate change on the communities surrounding the Bantimurung Bulusaraung National Park was carried out in the eastern part of Indonesia (Barkey et al., 2019b).

4 CLIMATE CHANGE CHALLENGES AND ADAPTATION TO DROUGHT IN INDONESIA

Despite the high rate of flood events, fewer drought reports are still observed. Figure 4 shows the distribution of study locations for projected drought events, using the RCP scenarios from AR5. In this case, the provincial, watershed, and island scales were also regionally utilized. Until 2021, only six drought publications were observed using the RCP scenarios, with the experimental locations not dominated by one area. However, two publications did not state the types of models used in processing climate change scenario data.

Drought conditions have also been tested in several Indonesian locations, such as in Bantimurung Bulusaraung National Park, South Sulawesi Province. In this case, RCP4.6 and RCP6.0 were used to analyze the susceptibility of the disaster.

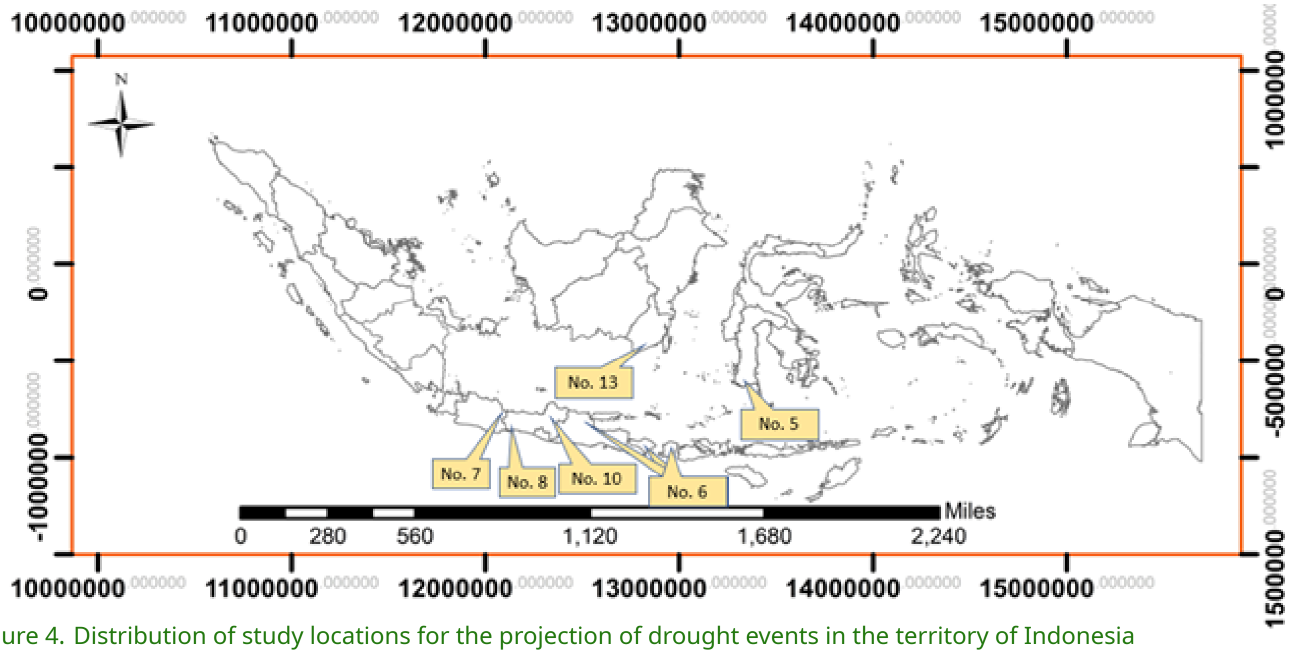

Figure 4. Distribution of study locations for the projection of drought events in the territory of Indonesia

Based on the VMA (vulnerability model analysis), several village buffer areas of the Bantimurung Balasaraung National Park had very high levels of vulnerability to drought hazards (Barkey et al., 2019a). This was in line with the results obtained in the Cilacap and Cirebon areas in Central and West Java, respectively. These locations were predicted to increase the incidence of drought using the RCP4.5 scenario only (Nurlatifah et al., 2019; Pratiwi et al., 2018).

Using a drought index, a calculative assessment was also carried out in Southeast Kalimantan (Barito watershed) and Central Java Province (Bodri-Juwero, Notog, and Wlingi irrigation weirs). This hydrological index is expected to show an increase in drought severity in the next 30 years, with a longer duration subsequently anticipated on irrigation dams in Central Java (Levina and Hatmoko, 2019). In Barito Watershed, the potential for drought hazards is also expected to futuristically increase, using the Keetch-Byram Drought Index (KBDI) method. This method is often used to comparatively analyze the potential for drought and forest fire hazards in the Barito watershed (Farahnaz et al., 2020).

Indonesia is one of the countries with an agricultural reputation, specifically in the core productive provinces of Java, Bali, and Nusa Tenggara. In these areas, the incidence of drought has also been calculated using the Standardized Precipitation Index, with Java experiencing more rainfall reductions than Bali and Nusa Tenggara (Parkhurst et al., 2019).

Based on the various utilized climate change scenarios, an increase is expected in the future frequency of Indonesian drought events, leading to the need for appropriate adaptation measures as suitable problem-solving methods. Since this disaster significantly influences the agricultural sector negatively, local communities need to adopt the plantation of drought-resistant cultivars (Widiyanti and Dittmann, 2014). The implementation of various adaptation measures also depends on the type of sectors affected by the drought occurrences in Indonesia (Kuswanto et al., 2019; Rondhi et al., 2019; Saptutyningsih et al., 2020).

5 CONCLUSION

Based on the results, only ten and six publications emphasized flood and drought events in Indonesia, respectively. Using the climate change scenarios from the IPCC AR5, the flood publications were mostly carried out in Jakarta due to being the country's capital city, which is often flooded. In this case, the RCP utilization for each report varied greatly, indicating that RCP8.5, RCP6.0, RCP4.5, and RCP2.6 were selected 9, 5, 12, and 4 times, respectively. Regarding the projections, climate change posed great challenges through flood and drought. In this case, several adaptation measures have been assessed and evaluated in solving future climate change predictions.

DISCLAIMER

The authors declare no conflict of interest.

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