Initiative use of climate change hotspots for targeting adaptation sites in Indonesia

Ikrom Mustofa1, Perdinan2*, Syafararisa Dian Pratiwi1, Suvany Aprilia1, Raden Eliasar Prabowo Tjahjono1, Sabila Cahyaning Janna1, Arif Wibowo1, Kardono3, Koko Wijanarka3

1PI AREA Environment & Technology
2Department of Geophysics and Meteorology, IPB University
3The Directorate of Climate Change Adaptation, Ministry of Environment and Forestry

Email: *perdinan@ipb.apps.ac.id

Abstract. Designing climate change adaptation actions are considerably a challenge, as the actions should be targeted uniquely addressing climate change impacts. One of the challenges is to determine climate change adaptation sites. The complexity raises considering climate change impact a wide range of economic sectors, which require a lot of resources to conduct a comprehensive climate change assessments. This study proposes the use of climate change hotspots as an initiative to firstly consider the potential targeted sites. The target of global efforts to maintain air temperature under 2°C was employed as a clue to prioritize areas that air temperature is increasing beyond the thresholds to which can affect human activities. This study employed spatial and threshold analysis to develop climate change hotspots of projected temperature change for 2021-2050 over Indonesia. The thresholds were defined by considering the effects of base temperature of 32 °C, 35 °C, and 38 °C on agriculture, environment, and human health in combination with elevated temperature from 0.75 to 2 °C. The initiative method was applied to the baseline and projected air temperature obtained from higher resolution of climate model outputs simulated under representative carbon pathway scenario of 4.5 (RCP 4.5 and 8.5) as a case study. The maps of climate change hotspots provide the potential targeted areas for climate change adaptation actions. Referring to the target of suppressing global temperatures below 2°C, we identified the distribution of climate change hotspots in Indonesia with a scenario of increasing temperature of 2°C from baseline conditions so that future air temperatures will be more than 35°C. The maps can also be combined with the other maps related to climate change analyses, which are available in Indonesia such as SIDIK to refine the priority areas and/or more general geographic information such as city location. As an example, the overlay of climate change hotspots and city location can provide early anticipation on which city will experience urban heat island. The development of climate change hotspots nationally is also expected to initiate climate change services that can be provided to the end users to ease them in defining suitable actions to adapt to the impacts of climate change.

Keywords: Climate change, adaptation, hotspots, site, air temperature, threshold
1. Introduction

1.1 Background
Climate change is a global problem affecting human livelihoods. For example, the impacts of climate change [1,2] are expected to pose serious challenges in the global food supply to meet the food consumption demands of an estimated nine billion human populations by 2050 [3, 4, 5]. In Indonesia, climate change directly or indirectly has an impact on the national economy through various aspects of the country development. Based on the analysis conducted by the Ministry of Environment and Forestry (MoEF) (2020), the potential impacts of climate change on the food, water, energy and health sectors could reduce National GDP by 3.45% by 2030. This impact can be exacerbated by the increasing frequency of disasters that may occur due to climate change in the future.

The Indonesian government has committed to take adaptation steps to reduce the risk of climate change impacts as part of development planning. This commitment is shown by the inclusion of the issue of addressing climate change in Indonesia’s 2020-2025 RPJMN in the National priority program No. 6: Building the Environment, Increasing Disaster Resilience and Climate Change. Various policy instruments have been developed in order to support efforts to reduce risks and impacts of climate change, including the Minister of Environment and Forestry Regulation No. 33 of 2016 concerning Guidelines for Formulating Climate Change Adaptation Actions, the Minister of Environment and Forestry Regulation No. 7 of 2018 concerning Guidelines for the Assessment of Vulnerability, Risk and Impact of Climate Change, as well as the National Action Plan for Climate Change Adaptation which was published in 2014. To support this instrument, MoEF has also developed a Vulnerability Index and Data Information System (SIDIK) which can be accessed at http://sidik.menlhk.go.id/. SIDIK provides data and information on socio-economic vulnerability with village units throughout Indonesia based on the socio-economic, demographic, geographic, and infrastructure environment data base published by the Central Bureau of Statistics (BPS).

The implementation of climate change adaptation is relatively complex considering Indonesia’s geographical position in the tropics, topographic variations, as well as land and sea areas. Thus, the critical step is to identify the targeted sites. One option is to identify the vulnerable areas to the potential impacts of climate change. This identification is important in assessing risks and designing targeted adaptation interventions [6]. The identification of the vulnerable areas can be determined by using the climate change hotspots to firstly identify areas impacted by the effects of global climate change to a specific region or area. Giorgi (2006) defines Climate Change Hotspot as an area whose climate is very responsive to global changes. In particular, a climate response-based hotspot characterization can provide key information for identifying and investigating key regional climate change impacts. Indonesia is one of the countries with the most significant climate change hotspots detected and has the potential to continue from time to time [6, 7]. The analysis generally shows strong changes in mean temperature and rainfall. These conditions suggest that the Climate Change Hotspots for the next few decades has emerged in its current state and adaptation strategies need to focus more on that region.

The impacts of climate change will continue to increase in line with population growth. Without a proper and serious strategy, people living in the hotspots will be more vulnerable and exacerbated by low socio-economic conditions. Coordination and integration efforts to address this challenge should be devised, as otherwise it may disrupt the development. This study proposes the use of climate change hotspots based on only air temperature analyses as an initiative to be considered in determining priority target locations for climate change adaptation interventions in Indonesia. We characterize the effects of global climate change in Indonesia in altering regional maximum temperatures and projected temperature changes of 0.75, 1, 1.5, 2°C. These changes are displayed spatially to identify the areas which will
experience air temperature beyond certain thresholds (i.e., 32 °C, 35 °C, and 38 °C). These areas are then proposed as the potential targeted sites for climate change adaptation. This identification of climate change hotspots offers a simplification for identifying targeted sites on a national coverage. Indeed, additional analyses to other climate variables (e.g., rainfall, humidity) and assessment of climate change impacts on sectors (e.g., food, waters) can further refine the determination of the targeted sites and also proposed specific adaptation options that can be implemented in specific locations.

2. Climate Change Hotspots

2.1 Definition of Climate Change Hotspots

IPCC in the Fifth Assessment Report - AR5 2014 defines climate change hotspots as areas characterized by high vulnerability and exposure/responsiveness to climate change. Giorgi (2006) and de Sherbinin (2014) also define climate change hotspots as areas that display the greatest variation in various statistics (average, variability, and extreme) of climate variables. A study conducted in 2015 [8] identified three types of climate change hotspots, which are: (1) Delta in Africa and South Asia; (2) Semi-arid regions in Africa and parts of southern and central Asia; (3) river valleys that depend on glaciers and snow, especially in the Himalayas.

![Figure 1. Climate change hotspot requiring focused attention using the SDG indicator framework [9]](image)

People who live in climate change hotspots are very dependent on the surrounding environment so that they will be more threatened by changes in temperature, rainfall or seasons. Under normal circumstances, these people can diversify their opinions and become more resilient by developing their economies. However, it will also have an external impact such as the drought in southern and eastern Africa occurred in 2016. This will have a negative impact affecting food security and nutrition which can lead to hunger, especially among vulnerable people.

An increase in temperature will provide a change in the pattern and distribution of rainfall. Based on this experience, the areas that are in water shortage or dry areas will be drier, and areas that are in wet conditions will be disturbed by the sustainability of their water resources. Stern (2007) justified the potential impacts caused by rising temperatures will affect many fields related to the national
development system such as the economy, life order, ecosystems, and others. The increase in air temperature beyond 2 °C has an impact on 1) decreasing crop yields, especially in developing countries, 2) water availability, small icebergs begin to disappear and sea level rises, 3) damage to coral reefs and an increased number of species extinction, 4) increased storm intensity, forest fires, drought, floods and heat waves [10]. Consequently, the target of global efforts to keep air temperatures below 2°C is used as a guide to prioritize areas where the temperature increases beyond a threshold that could affect human activities. The threshold is determined considering the effects of baseline temperatures (32 °C, 35 °C, and 38°C) on agriculture, the environment and human health. The baseline temperatures were used to considering varying impacts from region to region globally. For the mid to high latitude regions, the Intergovernmental Panel on Climate Change’s (IPCC) Fourth Assessment Report suggested that moderate increases in temperature (1-2°C) have small beneficial impacts on crop yields [10].

In this study, the basis for determining the climate change hotspots considers the Nationally Determined Contribution (NDC) that is the government's commitment to maintain an increase in earth temperature by 1.5 °C in the form of a GHG emission reduction target of 29% to 41% in 2030 compared to Business as Usual. In addition, the foundation of the climate change hotspots also refers to the target of increasing the resiliency of the economy, social and livelihoods, and the landscape ecosystem. In other words, adaptation actions should be targeted for areas where an increase in temperature is about 1.5°C or not beyond 2°C.

2.2 Implication of Climate Change Hotspots

The Intergovernmental UN assessment of climate change considers which areas or populations are vulnerable to the health impacts of climate change:

- Areas or populations bordering areas with endemicity of climate sensitive diseases (e.g. malaria and diarrhea).
- Areas exposed to disease due to extreme weather (e.g. epidemics related to El Nino weather patterns).
- Areas at risk of health-relevant impacts of climate change (e.g. food and water and risk of flooding).
- Areas at risk from concurrent environmental or socio-economic stresses with little adaptive capacity.

Rainfall-related extremes show more geographic variations with increases and decreases, both in heavy rainfall and drought. Hotspot mapping has been carried out by conservationists to select locations that apply limited resources so that the world’s biodiversity can be properly conserved. However, impacts can occur at the local level and identify areas or countries that are vulnerable to climate change. The following are the results of the identification [11]:

1. Hotspot – Heat waves or air pollution

These hotspots are found in cities that are geographically expanding and replacing vegetation with heat-retaining surfaces (for example, asphalt and tar roofs). In addition, there are also cities with poor quality housing that experience the urban heat island effect, and cities with topographies that create stagnant air masses and pose a risk of pollution in the summer (for example, Santiago and Mexico City). This is because an increase in environmental temperature and changes in wind patterns and air masses can affect the chemistry in the atmosphere. Vulnerability to heat waves is driven by socio-economic factors such as poor housing. Therefore, cities in developing countries may be more vulnerable to heat waves.
2. Hotspot – Sea Level Rise
These hotspots are found in residential areas in lowland deltas or coral atolls and large cities on the coast (such as Cairo, Egypt). After sea level rise, flooding will expand, and coastal erosion is expected in lowland coastal settlements. The number of people at risk of flooding caused by sea storms is projected to increase from 75 million to 200 million under the climate scenario [12]. Countries such as Vietnam, Egypt, Bangladesh and small island nations will be particularly vulnerable. Raised seawater can saline coastal freshwater aquifers and interfere with rainwater drainage and sewage.

3. Hotspot – Flood
This hotspot consists of areas prone to flooding in rivers, such as Central America, Europe, South Asia and China.

4. Hotspot – Drought and Malnutrition
These hotspots comprise areas that are currently experiencing food insecurity and drought risk along with a lack of resources to import food (e.g. southern and eastern Africa, parts of Latin America, and central Asia).

5. Hotspot – El Nino Effects
These hotspots consist of areas that experience extreme weather related to El-Nino weather patterns (for example, Peru and Ecuador for floods; South Africa, Indonesia, and Malaysia for drought; and some areas where infectious diseases are spread, such as malaria in Punjab or cholera in Bangladesh). Climate change is likely to cause extreme drought and rainfall, coupled with an El-Nino that increases the risk of drought and flooding occurring.

6. Hotspot – Highland malaria
These hotspots consist of areas located on the outskirts of malaria endemic areas (e.g. East Africa). Vector-borne diseases, such as malaria and dengue fever, are generally more affected by environmental conditions than diseases that are transmitted directly from person to person. Host populations for non-human mammals, such as rodents, are affected by habitat and weather conditions. Southern Africa, the Mediterranean, North Pole, and Central America to the northern part of the west are regional areas identified as climate change hotspots. Specific impacts are shaped by the interaction of climate change with a biophysical human vulnerability.

3. Approach and Methodology

3.1 Approach
The target of global efforts to keep air temperatures below 2°C is used as a guide to prioritize areas where the temperature increases beyond a threshold that could affect human activities. The threshold is determined taking into account the effects of baseline temperatures (32, 35, and 38°C) on agriculture, environment and human health with a combination of projected climate change temperatures from 0.75 °C to 2°C. After the climate change hotspot priority area is obtained, the next step is to assess adaptation directions and actions to reduce the impact of climate change. Over the next thirty years, climate change is inevitable. So that adaptation is needed to respond to climate change. Adaptation is an important policy response, and the international community must find ways to support adaptation, especially in the most vulnerable countries [13]. The illustration of the general approach is in Figure 2.
3.2 Methodology

The modeling uses the global output climate model data produced by Worldclim. Worldclim [14] was developed by Robert J. Hijmans, Susan Cameron, and Juan Parra, at the Museum of Vertebrate Zoology, University of California, Berkeley, in collaboration with Peter Jones and Andrew Jarvis (CIAT), and with Karen Richardson (Rainforest CRC). Worldclim data is an interpolation development of surface climate elements for areas with a resolution of 1 km. The scenarios used are the RCP 4.5 and RCP 8.5 scenarios. The RCP 4.5 scenario is a moderate category scenario with the assumption that the target is to overcome the rate of increase in global average air temperature due to anthropogenic factors which is still possible. The RCP 4.5 scenario is a climate change scenario in which the total radiative forcing stabilizes rapidly beyond the long-term target level of radiative forcing [15]. Meanwhile RCP 8.5 is a scenario developed using the MESSAGE and IIASA models, which are characterized by an increase in greenhouse gas emissions over time which leads to high levels of greenhouse gas concentrations [16].

The models used are the CSIRO and MIROC models as part of the Worldclim database. The data used for developing climate change hotspots are:

a. Projected change in temperature (.tif)
   Projections of future temperature changes are determined using the CSIRO and MIROC models with RCP 4.5 and RCP 8.5 scenarios
b. Maximum temperature (.tif)
   Use model data to assess how much temperature extremes might change in the future.

According to the global atlas issued by the IPCC 2013, Indonesia is projected to experience an increase in air temperature of up to 2°C or beyond on major islands in Indonesia by 2100 [17]. Referring to the target of reducing global temperatures below 2°C, the distribution of climate change hotspots in Indonesia is mapped, based on regional conditions that have the potential to experience an increase in temperature of 0.75°C – 2°C from baseline conditions so that future air temperatures will reach 32°C, 35°C, and 38°C. The temperature of 35°C was chosen as the threshold where food, water and ecosystems are affected by climate change, while at 38°C, climate change will have the potential to disrupt the health of living things. The effects of increasing air temperature may vary by region. For example, an increase in temperature of 2°C will have a very negative impact on areas with a maximum current condition of
36°C, but this increase does not necessarily have a significant impact on areas that are currently 22°C because they are still within the comfort threshold of air temperature in that region [18].

The analysis of climate change hotspots is illustrated in Figure 3. The procedure applied in geographical information system (GIS) to process air temperature data illustrated in Figure 3 are described below.

1. Apply GIS analysis to process the base-air temperature and temperature changes. The grid resolution of the two datasets set equally the same.
2. Use the tools named “Raster Calculator” to group data on temperature change using the if condition where any temperature change over 2°C is converted into 1, and those below 2°C is converted into 0 (i.e., if temperature change > 2, 1, 0).
3. Apply the same procedure as point 2 to group data on maximum temperature data where any data above 35°C is converted into 1, while those below 35°C is converted into 0 (i.e., if air temperature > 35, 1, 0).
4. Use the Raster Calculator to multiply the results of Point 2 and Point 3, if the multiplication is 1, then assigns the grids as climate change hotspot.
5. Visualize the results of Point 4 into a map and overlay with other data such as vulnerability, health, and others for additional consideration in determining the targeted sites.

Figure 3. Flow chart of the method on making a climate change hotspot map

4. Utilization of Climate Change Hotspots

The importance of identifying climate change hotspots in efforts to identify locations with the strong climate change signals is considered as a challenge [19]. Referring to the target of suppressing global temperatures below 2°C, we identified the distribution of climate change hotspots in Indonesia with a scenario of increasing temperature of 2°C from baseline condition of air temperature is equal to 35°C (Figure 4). The temperature of 35°C was chosen with a consideration the potential impacts of the air temperature threshold on food, water and ecosystems. The effects of increasing temperature may vary by region so that applying the same baseline condition is important. For example, an increase in air
temperature of 2°C will have negative impacts on areas with a current condition of 36°C, but the same amount of increase does not necessarily have a significant impact on areas that currently have a baseline temperature of 22°C because they are still below the negative thresholds. Climate change hotspots on the map (Figure 4) are shown in red.

**Figure 4** Distribution of climate change hotspots derived based on only air temperature maximum with the baseline temperature of 35°C and temperature change is more than or equal to 2°C projected using representative carbon pathway (RCP) of 4.5 (top panels) and 8.5 (bottom panels)

The outputs of the RCP 8.5 scenario shows that the distribution of the hotspots is more than the RCP 4.5 (Figure 4 bottom panels). However, in general, it shows the same distribution location. The hotspots appear mostly in dry and transitional months such as March-April-May (MAM) and June-July-August (JJA). Many hotspots appear in Sumatra, eastern Kalimantan, western Java, and the coast of Papua. An example of extraction to identify climate change hotspots for the JJA under the RCP 4.5 displays that the hotspots generally appear on the islands of Sumatra and Kalimantan. However, the higher the temperature increase in the future; the less climate change hotspots are in the region. The general condition of projected climate change hotspots using CSIRO and MIROC global climate models as part of the Wordclim downscaled regional climate data for Indonesia under the RCP 4.5 are in Table 1.
**Table 1.** Identification of Climate Hotspots in Indonesia based on RCP 4.5 CSIRO and MIROC projections at various temperature increases (MoEF, 2020)

| Projection Temperature | Location of Climate Hotspots in June July August with increasing temperatures from baseline conditions |
|------------------------|--------------------------------------------------------------------------------------------------|
| >0.75°C                | >1°C                                                                                               |
| >1°C                   | >1.5°C                                                                                             |
| >2°C                   |                                                                                                   |
| 35°C                   | Most of Sumatra, Northern Java Island (Jakarta, Banten, northern West Java, and northern East Java) |
|                        | South Aceh, a little in North Sumatra, West Sumatra, South Sumatra                                |
|                        | A small part of the area is in North Sumatra, West Sumatra, Bengkulu and South Sumatra             |
|                        | Few points in Sumatra (Medan, West Sumatra, Jambi)                                                 |
|                        | Northern Java Island (Jakarta, Banten, northern West Java, and northern East Java)                |
|                        | A little of the western part of Java                                                               |
|                        | Few points in West Java and Jakarta                                                                  |
|                        | The western part of West Kalimantan and the southern part of Central Kalimantan                     |
|                        | A few areas in southern Central Kalimantan and Papua                                                 |
|                        | 2 points in Papua                                                                                   |
|                        | The western part of West Papua and Papua and a few areas in NTT and Central Sulawesi                |
|                        | A few areas in NTT, Papua and West Papua                                                             |
| 38°C                   | Most of Sumatra (North Sumatra, Aceh, Riau, South Sumatra, Lampung)                               |
|                        | Riau, South Sumatra, western Lampung Province, and West Sumatra                                    |
|                        | Several points in Sumatra (Aceh, Lampung, South Sumatra, West Sumatra)                             |
|                        | 2 points in Sumatra (West Sumatra, Lampung)                                                        |
|                        | A little of the western part of Java and East Java                                                 |
|                        | North East Java Region                                                                              |
|                        | Some locations in West Java and East Java                                                           |

The climate change hotspot shows an area whose climate is responsive to the signals of global climate change. This information can be used as a base for further analysis. The Government of Indonesia (GoI) through the Ministry of Environment and Forestry has issued information on the socio-economic vulnerability of the country spatially using a tool named Sistem Informasi Data Indeks Kerentanan (SIDIK) in English translated as System Information on Vulnerability Index. SIDIK provides data and information on spatial vulnerability with village units throughout Indonesia based on the socio-economic, demographic, geographic, and infrastructure environment database published by the Central...
Bureau of Statistics. The climate change hotspot maps (Figure 4) can support the SIDIK. As an example, the climate change hotspots are overlaid with the SIDIK (Figure 5). This overlay offers an interpretation to select areas which are socio-economic vulnerable and shows strong climate change signals with regards to the climate change hotspots.

Figure 5. Climate hotspot map with vulnerability map (SIDIK)

Figure 5 is a map of the vulnerability index combined with climate change hotspots for the RCP 4.5. This example of simple analysis by overlaying the two maps can provide a better situation to identify priority areas for intervention. The overlay shows that not all vulnerable areas are equally impacted by climate change. For example, settlements in the cities have good economic conditions and education levels as opposed to those in rural areas. Therefore, priority programs need to focus on areas that are potentially impacted by climate change and categorized into the highest vulnerable areas. This example can be further expanded for planning interventions as climate change hotspots are also prepared for different seasons (i.e., DJF, MAM, JJA, and SON) and the vulnerable rural areas are classified into different classes from the lowest to the highest (Figure 5). After, the priority areas have been identified, further analyses on the potential impact of climate change on specific sectors, such as food, water, energy, and health [18], can be conducted. This continuation analysis is proposed to determine suitable adaptation options for local climate change actions in minimizing the potential negative impacts of climate change and maximizing the potential positive impacts of climate change.

5. Discussion

The impacts of climate change will continue to increase, exacerbated with the increase of population, particularly Indonesia. Without a serious strategy and adaptation to address the impacts of climate change, the areas identified as climate change hotspots will be increasingly vulnerable. In September 2015, countries that are members of the UN agreed on 17 goals as part of the 2030 Agenda for Sustainable Development. This sustainable development goal is one that is specifically aimed at tackling and reducing the impact of climate change and the risks posed by climate change, especially among developing countries, including Indonesia. The advantages of the climate change hotspot that have been compiled are the procedure simplify the selection of targeted sites with regards to the change air
temperature targets (\( < 2^\circ\text{C} \)) and the baseline air temperature. The identified hotspots can further be overlaid with other data such as vulnerability data of SIDIK to determine the priority areas.

The implementation of climate change hotspots for defining climate change adaptation (CCA) requires commitment not only from the national government but also the sub-national governments, private sector, NGOs, and other stakeholders. In the Nationally Determined Indonesia (NDC) document, CCA strategy aims to reduce risk, increase adaptive capacity, strengthen resilience, and reduce vulnerability to climate change in all development sectors. This goal is pursued through increasing climate literacy, strengthening local capacity, improving knowledge management, converging policies on climate change adaptation and disaster risk reduction, and the application of adaptive technology [18]. The Indonesian government has provided guidelines for the preparation of climate change adaptation actions as stipulated in the Minister of Environment and Forestry Regulation No. 33 of 2016 concerning Guidelines for Formulating Climate Change Adaptation Actions. The regulation aims to provide guidelines for national and sub-national governments in preparing climate change adaptation action plans in integrating these plans into regional and/or sectoral development plans that consider the impacts of climate change. The stages of formulating climate change adaptation actions are carried out through: 1) Identification of target coverage of specific areas and/or sectors and the potential climate change impacts; 2) Preparation of climate risk and vulnerability assessments; 3) Formulation of climate change adaptation action options; 4) Determining priorities for climate change adaptation actions; and 5) Integrating climate change adaptation actions into development policies, plans and / or programs. To support this guideline, the government also issued the Minister of Environment and Forestry Regulation No. 7 of 2018 concerning Guidelines for the Assessment of Vulnerability, Risk and Impact of Climate Change. The essence of preparing climate change adaptation actions is to consider the formulation of focused issues in specific area and the utilization of climate change vulnerability, risks, and impacts. Information on climate change hotspots can be used in accordance with the preparation of adaptation actions. The climate change hotspots in combination with the SIDIK vulnerability information can be used to determine priority areas for adaptation actions as illustrated in Figure 6.

**Figure 6.** The inclusion of climate change hotspots in modifying steps to formulate climate change adaptation actions as guided by the Ministerial Decree No. 33/2016 and No.7/2018
Once the priority areas are identified, further analysis can be deployed to measure the impacts of climate change on specific sectors in the areas. This additional analysis is needed to set potential options for adaptation actions. The actions reflect the need for adaptation in institutional aspects and increase the capacity of human resources, the provision and availability of technology and financial support [20]. Therefore, the choice of adaptation should be committed by the stakeholders. In the context of implementing adaptation actions, the time for actions can be grouped based on the urgency of the interventions into short-, medium- and long-term actions. This can be identified based on factors of the emergence of climate hotspots, levels of vulnerability and risk. For example, the emergence of the hotspots more frequently in all seasons coupled with the socio-economic level of vulnerability in high disaster risk areas will need immediate interventions, and should be included in the short-term plan. On the other hand, the frequent emergence of the hotspots but in locations with a low level of vulnerability may be assigned as an area in the category of long-term intervention. This category means the community will be able to survive, but the interventions are still needed in the long run.

6. Conclusion

This study proposes the use of climate change hotspots as an initiative to be considered in determining the target locations for climate change adaptation interventions in Indonesia. The use of climate change hotspots in combination with vulnerability data such as SIDIK offer an alternative to ease the selection of targeted sites for adaptation actions. This selection is critical to reduce the workloads required to conduct the further details of climate change impact assessment on specific sector as the impacted sectors may vary from location to location.

This study simplified the identification of climate change hotspots based on only air temperature data allowing the analyses to cover the entire islands of Indonesia. Climate change hotspots of projected temperature change for 2021-2050 over Indonesia were developed using spatial and threshold analysis. The thresholds were defined by considering the effects of base temperature of 32 °C, 35 °C, and 38 °C on agriculture, environment, and human health in combination with elevated temperature from 0.75 to 2 °C. The procedure was applied using GIS analysis to the baseline and projected air temperature of higher resolution of climate model outputs RCP 4.5 and 8.5 as a case study.

The results revealed that the RCP 8.5 scenario shows the distribution of climate change hotspots is more than the RCP 4.5; although, it shows generally the same distributed locations. Climate change hotspots appear mostly in dry and transitional months such as March-April-May (MAM) and June-July-August (JJA). The relatively large areas of hotspots appear in Sumatra, eastern Kalimantan, western Java, and the coast of Papua. However, the higher the temperature increase in the future; the less climate change hotspots are in the region.

One of the potential uses of the hotspots is the overlay of climate change hotspots with city locations to provide early anticipation on which city will experience urban heat island. The development of climate change hotspots nationally is also expected to initiate climate change services that can be provided to the end users to ease them in defining suitable actions to adapt to the impacts of climate change. The provision of climate change hotspots must be combined with the other datasets to allow for a better interpretation of the use climate change hotspots. Further works can be conducted to develop climate change hotspots based on other climate variables such as rainfall and humidity considering the complexity of climate change impacts on a wide range of sectors where air temperature is not the solely climate variable dictating the impacts of climate condition in a region. This further development of climate change hotspots based on rainfall data can provide a better use of climate change hotspots for
meso to micro scale analysis considering rainfall is more vary to regional and seasonal condition in
Indonesia. A cooperation among stakeholders in the principle of no-one left behind should also be
considered so that the outputs or products can be used properly and widely in the country.

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