Economic losses analysis due to the impact of climate change on the health sector in Indonesia

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Abstract. Changes in environmental conditions due to climate change have the potential to change the pattern of disease spread and reduce the degree of human health. Health is a human right and a vital factor for human activity. Indirectly, health plays an important role in supporting economic activity and national development. This study aims to analyze the potential economic losses to the health sector due to climate change. The economic impact is calculated from losses through increasing the prevalence of climate sensitive diseases in the future, including dengue fever, malaria, diarrhea, and pneumonia. The distribution of diseases based on climatic factors is used to estimate the total prevalence. The number of disease prevalence was obtained by sensitivity analysis which was adjusted to the results of the RCP 4.5 CSIRO and MIROC models. The results showed that the impact of climate change on climate sensitive diseases has the potential to affect Indonesia's Gross Domestic Product (GDP) by 0.1% or equivalent to Rp. 7.6 trillion. Climate change is projected to trigger disasters more frequently, thus increasing health losses by up to 1.8% of Indonesia's national GDP. Strengthening climate change adaptation action in the health sector needs more attention to reduce these losses.

1. Introduction
The impact of climate change will slowly but surely be felt by various sectors of life. Climate change in Indonesia not only has implications for the country's environment, but it also greatly affects its people and development [1] including economy, poor population, and human health [2]. One area that is impacted by all others as a result of climate risk is environmental and human health. Climate risk to environmental and human health is considered a global challenge because health is a basic human right, health also one of the main development goals [3,4]. In addition, health is closely related to the country's economy. Because, if humans are sick, it will interfere with their activities and have an impact on productivity in various economic sectors.

Human health will be affected by the impacts of climate change both directly and indirectly [1]. The impact that may be felt directly is death due to climate-related hazards. The impact is also exacerbated by the increasing hydrometeorology disaster including floods, droughts, erosions, and extreme weather
The indirect impact is an increase in infections and diseases due to the wider spread of disease vectors and the expansion of diseases transmitted through poor environmental conditions [1]. Changes in specific climatic variables including temperature, rainfall patterns, and extreme weather events are expected to influence—more likely to exacerbate—the emergence or re-emergence of many vector-borne diseases [2].

The attention of the Indonesian government in controlling climate change continues to increase. This is indicated by the inclusion of the climate change issue in the 2020 – 2024 National Mid-Term Development Plan (RPJMN) in National Priority No. 6: Building the Environment, Improving Disaster and Climate Change Resilience. The health sector through the Ministry of Health has given special attention to climate change since the late 2000s with the issuance of Law 36/2009 on Health Protection and Environmental Management. Various legal products and guidelines related to environmental health have also been developed, i.e. The National Action Plan for Climate Change in the Health Sector, Climate Healthy Village Guidelines (Desa Desi), and Curriculum and Training Modules for Health Sector Climate Change Adaptation Trainers (APIK).

A strategic approach is needed to ensure that climate change control measures in the health sector are timely and effective. This strategic approach requires an objective understanding of the economic and financial impacts of climate change and the alternative and complementary actions available to respond this health threat [8]. Particularly, action planning must consider the costs and benefits to be incurred to remain relevant to the possible harm from the occurrence of the disease. The purpose of the health costs analysis due to climate change is to show the real impacts of how costly future climate-sensitive events may be, given our understanding of recent climate impacts on health [9]. In addition, to demonstrate to decision-makers and to provide advocacy material to raise awareness about climate change, highlighting the value of health effects and the need to prevent or reduce [8]. Economic loss estimation also can help society assess whether investments in climate adaptation measures are achieving their intended benefits [10, 7].

Various studies of economic loss in the health sector have been carried out in other countries such as in the United State by estimating the number of deaths, hospitalizations, emergency department visits, and medical care [7, 3]. Some studies have also included the cost of treating additional cases of disease [9, 6]. In this study, we analyze economic loss in the health sector in Indonesia based on the prevalence of climate-sensitive diseases, including DHF, diarrhea, malaria, and pneumonia. The prevalence is limited to the potential spread of disease due to environmental conditions based on the RCP 4.5 climate change scenario and hydrometeorological disaster events. The cost of treatment, hospitalization, and the cost of losses due to not being able to work while sick is also taken into account in the analysis.

2. Method

2.1. Data and Assumptions

This study uses secondary data consisting of climate data and health data as well as other supporting data. Then, the data processed using spatial and numerical software. The data sources are detailed in Table 1.

Table 1. Secondary data for calculation of economic loss in the health sector.

| Data                          | Period   | Source                                      |
|-------------------------------|----------|---------------------------------------------|
| Baseline temperature          | 1991 – 2020 | http://www.ccafs-climate.org/               |
| Temperature RCP 4.5           | 2021 – 2050 |                                             |
| Baseline extreme temperature  | 1991 – 2020 | https://portal.nccs.nasa.gov/datashare/      |
| Extreme temperature RCP 4.5  | 2021 – 2050 | NEXGDDP/BCSD/                              |
| Baseline precipitation        | 1991 – 2020 | http://www.ccafs-climate.org/               |
| Precipitation RCP 4.5         | 2021 – 2050 |                                             |
| Baseline extreme precipitation| 1991 – 2020 | https://portal.nccs.nasa.gov/datashare/      |
| Extreme precipitation RCP 4.5 | 2021 – 2050 | NEXGDDP/BCSD/                              |
Some of the assumptions used include:

a. Climatic factors in the form of rainfall and air temperature affect the impact of disease incidence.

b. The average baseline temperature is 28.1°C and precipitation is 2,976 mm, while the Indonesia's GDP in 2010 was IDR 7,399 T.

c. Sensitivity analysis using projected future air temperature changes against the baseline year ranges from 1°C to 3°C and changes in future rainfall against the baseline year is -30% to 30%. This is referring to climate projections RCP 4.5 CSIRO and MIROC models, taking into account the results of the BMKG study and various state documents related to climate change.

2.2. Approach
The economic loss in the health sector is analyzed based on the changes in disease prevalence in the future. The types of diseases that are calculated are climate-sensitive diseases, including dengue fever (DHF), malaria, diarrhea, and pneumonia. Impact assessment is carried out by calculating the ratio of losses resulting from increasing the number of disease prevalence. The loss ratio is also carried out on the incidence of disease distribution due to floods, landslides, and droughts which are projected to increase due to the climate change phenomenon. The number of disease prevalence was obtained by sensitivity analysis which was adjusted to the results of the RCP 4.5 CSIRO and MIROC models, where future temperatures increased by about 1°C to 3°C and rainfall changes up to 30% from baseline conditions. Sensitivity analysis is used to cover various scenarios and projections that already exist in various studies in Indonesia.

2.3. Impact Calculation of Disease Event Losses
2.3.1. Projection of Total Patient
Total affected patient is a function of the number patients at baseline (incidence rate/IR) with the area affected

\[ \text{Projection of Total Patient} = \text{IR Baseline} + (\text{Affected area} \times \text{IR baseline}) \]  \hspace{1cm} (1)

The IR is calculated for each type of disease in 2010 obtained from the Ministry of Health. The IR can be calculated based on the number of disease occurrences per thousand population:

\[ \text{IR Baseline} = \left( \frac{\text{Number of Diseases}}{\text{Total Population}} \right) \times 100,000 \]  \hspace{1cm} (2)

Meanwhile, the affected area is analyzed by modeling climate data that influences disease incidence using RCP 4.5 with CSIRO and MIROC models. Then we calculating the difference area projected and the baseline. In addition, the affected area is also calculated based on a comparison of the percentage of the incident impact based on disaster (floods, droughts, and landslides) in 2010-2018.
2.3.2. **Value of a Prevented Fatality (VPF)**
The VPF is obtained through the case fatality rate for each disease (CFR) which is assumed to be a fixed value, the number of patients, the normal period of work which symbolizes the length of time a person works in his life, and the GDP per capita of the Indonesian population.

\[
VPF = (CFR \times Total\ Patient) \times Normal\ Period\ of\ Work \times National\ GDP
\]  
with:

- **VPF**: Value of a Prevented Fatality (IDR)
- **CFR**: DHF (0.72%); Malaria (0.02%); Diarrhea (3.04%); Pneumonia (0.07%)
- **Normal Period of Work**: Retirement Age – Early Working Age (42 Years Old)

2.3.3. **Value of a Life Year (VOLY)**
The VOLY is obtained by calculating the length of time a person has been hospitalized due to disease incidence, number of patients, and National GDP per capita to get the average value of income.

\[
VOLY = \left(\frac{Length\ of\ Hospitalization}{365}\right) \times Total\ Patient \times National\ GDP
\]  
with:

- **VOLY**: Value of a Life Year (IDR)
- **Length of Hospitalization**: DHF (11 days); Malaria (6 days); Diarrhea (5 days); Pneumonia (7 days)
- **Number of days in a year**: 365 days

2.3.4. **Hospital Admission Costs (HAC)**
The HAC is obtained by calculating the average hospital administrative costs and the number of patients. The lowest assumption of hospital costs is IDR 50,000.00 per day

\[
HAC = Hospital\ Cost \times Total\ Patient
\]  

2.3.5. **Total Cost of Disease Incidence (TC)**
The TC is obtained through the value of prevention death, the value of years of life, and hospital administration costs.

\[
TC = VPF + VOLY + HAC
\]  

2.3.6. **Ratio of Climate Change Impact to National GDP Value**
GDP is basically the total value of final goods and services produced by all economic units. The ratio of the impact of climate change is expressed in units of %. Calculation of the ratio of the impact of climate change to GDP is carried out using the following equation:

\[
Ratio = \left(\frac{TC}{National\ GDP}\right) \times 100\%
\]  

3. **Result and Discussion**

3.1. **The Pattern of Diseases Occurrence**
Disease incidence is not only caused by climate and environmental change, but also by determinants of social and environmental health – clean air, safe drinking water, adequate food, and safe housing [7]. The theory of H.L. Blum said that health status is determined by 40% of environmental factors, 30% of behavioral factors, 20% of health care factors, and 10% of genetic factors (heredity). Increased climate extremes can cause environmental problems that will increase disease transmission. Infectious diseases that will appear and spread during the rainy and flood seasons are acute respiratory infections (ARI),
dengue fever, diarrhea, leptospirosis, malaria, skin diseases, and possibly bird flu [4]. The beginning of the dry season will increase the risk of diarrhea [1].

Figure 1. Distribution of disease incidence (a) DHF; (b) Diarrhea; (c) Malaria; (d) Pneumonia at baseline and future projections.
Climate change causes an increase in surface temperature and rainfall patterns, it will affect the increase and spread of diseases and their vectors through various media. The disease prevalence distribution map was prepared using disease vector climate thresholds based on the Health National Adaptation Plan document [1]. Indicative disease maps based on climatic conditions were corrected with disease incidence maps compiled based on historical information on 2016-2018 events. Potential future disease events were mapped based on the RCP 4.5 with CSIRO and MIROC models. Hazard map analysis is simulated through a grid approach, while validation/correction is carried out using an incident information approach at the provincial level.

The disease index value indicates the level of potential disease occurrence in the areas of Indonesia (figure 1), the redder indicates the potential for higher incidences in the future. The maps show that the vectors of dengue, diarrhea, and malaria can live in most areas in Indonesia. Meanwhile, pneumonia vectors can live in highland areas in Indonesia. In the future conditions shows that climate change conditions have the potential to increase disease incidence. In urban areas on the island of Java, this potential generally occurs in large cities with a high population. DHF has a high potential to occur in eastern Indonesia, Kalimantan Island, and parts of Sumatra Island, and along the coast of Java Island (figure 2a). The distribution of diarrheal disease (figure 2b) in the CSIRO 2021-2050 projection shows an increased potential incidence to occur in Bengkulu and West Sumatra, Western and Central Kalimantan, Central Sulawesi, Banten, DKI Jakarta, and West Java, as well as most of Papua and West Papua Province. The MIROC model also shows the same results, but with a higher and wider potential. Figure 2c shows that Papua and Kalimantan are endemic areas for malaria disease. Meanwhile, the pneumonia disease index was not as high as the other climate-sensitive diseases (figure 2d). The highest incidence potential is in the highlands of Papua and Belitung Island. However, pneumonia still has the potential to increase in the future. Significant increases were seen in the areas of Aceh, North Sumatra, and West Sumatra Province. In addition, the northern part of Java Island also projected to potentially increase the pneumonia incidence.

3.2. The Impact of Climate Change on the Change of Diseases Pattern
Climate change can be expected to have direct impacts on the distribution of insects and ticks that transmit infectious diseases [11]. For example, recent results in Kenya show that anomalies in climate variability account for up to 26% of anomalies in hospital-based highland malaria cases [12]. It is estimated that by 2100 the global average temperature will increase by 1.0 – 3.5°C, which will increase the likelihood of many vector-borne diseases in new areas. The drastic increase in temperature in the last few decades is expected to increase the intensity of vector-borne diseases in areas that have already been infected [11]. The greatest effect occurs in the extreme temperature range over which transmission occurs. Most of the vector-borne diseases are in the range of 14 – 18°C at the lower limit and around 35 – 40°C at the upper limit. Warmer temperature conditions mainly during the rainy season, both contributing to high humidity levels, allow tropical mosquitos to flourish, thus, promoting the occurrence of Aedes-borne outbreaks and persistent virus circulation between host and vector populations [13]. The most common vector-borne diseases in the tropics and subtropics are malaria and dengue [12].

Malaria transmission is temperature sensitive, since mosquito survival and parasite development for subsequent transmission is a critical factor in driving the epidemiology of malaria. Temperature and rainfall are also limiting factors in mosquito ecology. The climate anomalies associated with the El Nino–Southern Oscillation phenomenon are expected to result in an increase in the frequency and intensity of droughts and floods. This is associated with increasing malaria outbreaks in Africa, Asia and South America [12]. Excessive rainfall may result in flash floods, which may destroy mosquito eggs or wash away larvae. Increased rainfall and flooding events may increase the potential vector breeding sites and habitats for mosquito larvae. However, excessive rainfall may result in flash floods, which may destroy mosquito eggs or wash away larvae. A statistically significant effect of climate change on the increasing incidence of malaria is still possible, but, given the wealth of evidence for other causative factors for these increases. In addition, the role of climate change on the geographic distribution of
malaria remains uncertain. This is especially true in relation to upland malaria (malaria outbreaks in previously unrecorded highland transmission sites).

Moreover, an increase in temperature causes an increase in survival and feeding activity, as well the rate of development of the pathogen within the vector. The extrinsic incubation period (the time between ingestion of the pathogen by the vector and the vector becoming infective) for the dengue virus has been found to be inversely associated with ambient temperature. Relationships between temperature and vector survival, abundance and feeding behavior are often complex \[14\]. Based on the results of research by [15] that the geographic range of Aedes aegypti (and other vectors) is limited by cooler environmental temperatures. Climate change is causing the earth to warm in some areas, thus it is feared that mosquitoes and viruses will spread to higher latitudes and altitudes, and the transmission season will be longer in some endemic areas. There is also the possibility of a reduction in the incidence of dengue or other vector-borne diseases in endemic areas if it becomes so hot that survival or vector feeding is impeded. In addition to rising temperatures, increased rainfall as a result of climate change can provide more vector breeding grounds; however, drought can also provide more breeding grounds due to increased use of containers for rainwater collection and storage (a major breeding ground for A. aegypti) \[14\].

3.3. Economic losses in the health sector
In general, the basic needs of living things include the fulfillment of food, water and energy, as well health (healthy environment). The provision of these basic needs is influenced by the availability of ecosystem services and disaster events. The condition of environmental and human health is a reflection of human interaction with the environment and the surrounding ecosystem. Waste and residue from the activities of living things will affect the system for providing basic needs and human health. The agreed impact assessment indicator is the risk of the impact of climate change on the fulfillment of basic needs production as reflected in the value of National GDP.

Environmental and human health is also impacted by the climate risk. Health is the basis for humans to be able to carry out their activities. Health will affect human productivity which of course has an impact on daily activities in supporting various aspects of life including economics, politics, and development. The results of the losses estimation in the health sector ranging from 0.05% to 1.86% of the National GDP (Table 2). This calculation has not taken into account the impact of the COVID-19 pandemic. Thus, it might be underestimated. However, this is more than enough to prove that the health sector is severely impacted and needs serious attention.

Table 2. The result of economic losses analysis.

| No | Condition                                      | Estimation of Economic Losses (IDR)    | Ratio of losses to National GDP (%) |
|----|------------------------------------------------|---------------------------------------|------------------------------------|
| [1]| CSIRO 4.5                                      | -3,392,090,766,310                   | -0.05                              |
| [2]| MIROC 4.5                                      | -11,956,726,795,255                  | -0.16                              |
| [3]| Due to Climate Change (average [1]+[2])        | -7,674,408,780,782                   | -0.10                              |
| [4]| Due to Disasters                               | -125,692,596,207,262                 | -1.70                              |
|    | [3] + [4]                                      | -133,367,004,988,044                 | -1.80                              |
|    | [4] + [1]                                      | -129,084,686,973,572                 | -1.75                              |
|    | [4] + [2]                                      | -137,649,323,002,517                 | -1.86                              |
|    | Maximum Estimation Losses                      | -137,649,323,002,517                 | -1.86                              |
|    | Minimum Estimation Losses                      | -3,392,090,766,310                   | -0.05                              |

Climate change has an impact on health both directly and indirectly which is strongly influenced by environmental, social and public health determinants. Directly increasing weather and climate extremes can cause various environmental problems such as floods, landslides, and droughts. Changes and environmental damage due to rain and flooding have the potential to increase disease-causing vectors
and of course increase disease transmission. Meanwhile, air pollution caused by carbon emissions causes the deaths of more than 7 million people/year globally, and also causes 26% of deaths due to systemic liver disease [16]. Table 2 shows that the results of the analysis project that losses in the health sector due to climate change in Indonesia will affect the value of National GDP by 0.10% or around IDR 7.6 trillion.

Extreme weather due to climate change in the future has the potential to increase the incidence of disasters, especially hydrometeorological disasters. Based on DIBI BNPB data, in the period 2009 to 2019 there have been more than 19,469 hydrometeorological disasters in Indonesia. Losses due to disasters every year can reach 30.83% of National GDP with an average of 6.21% of Indonesia's National GDP.

Losses due to disasters can be exacerbated by decreasing environmental quality during disasters, causing health hazards, scarcity of clean water, and disruption of food production and distribution processes. The risk of disease occurrence can increase along with the increasing incidence of climate-related disasters such as floods and droughts. Floods can cause water-borne diseases and are breeding grounds for disease vectors, such as mosquitoes, rats. Meanwhile, drought can cause water scarcity which has implications for increasing community vulnerability. If in the future climate change also triggers catastrophic events simultaneously, then the impact on National GDP is estimated at 1.8% or around IDR 133.36 trillion (table 2). Given that every disaster event can cause a domino effect in other areas of life, it is very necessary to make efforts to reduce the risk of disaster events.

4. Conclusion
The results showed that the impact of climate change on climate sensitive diseases has the potential to affect Indonesia's GDP by 0.1% or equivalent to Rp. 7.6 trillion. Climate change is projected to trigger disasters more frequently, thus increasing health losses by up to 1.8% of Indonesia's national GDP. Strengthening climate change adaptation action in the health sector needs more attention to reduce these losses.

5. Recommendation
Considering the impact of climate change on the health sector, the government and all levels of society need to take part in the implementation of Climate Change Adaptation in the Health sector. Climate change adaptation strategies in the health sector need to be a priority as a form of support for the fulfillment of health rights. The government has developed policies and regulations in the health sector that support the implementation of the Climate Change Adaptation Plan in the Health sector starting from the law to ministerial regulations as the basis for preparing the implementation instructions and technical guidelines. Ministerial regulations that have been formed such as KEPMENKES No. HK.01.07/Menkes/423/2017 in the form of technical guidelines as implementation instructions, PERMENKES No. 1018/2011 in the form of guidelines for setting priorities for climate change adaptation options strategies, and the mandate of PERMENKES No.035/2012 which considers contributing factors to vulnerability and risk climate change on health [17].

Efforts to encourage coordination and synergy also need to be carried out with other institutions, especially sectors that have a direct impact on the implementation of Climate Change Adaptation on Health Sector such as BNPB, Ministry of Public Works and Housing (MPWH), BAPPENAS, Ministry of Home Affairs (MHA), and Ministry of Environment and Forestry (MoEF). Synergy efforts can be made through program mainstreaming and policy support. The identification of other institutions involved in the Climate Change Adaptation Plan in the Health sector effort and the potential for synergies and coordination are presented in the form of a matrix below [17].
Table 3. Identification of parties related to Climate Change Adaptation Plan in the Health sector implementation in Indonesia.

| Cooperation | Parties Involved | Potential for Synergy and Coordination of Activities |
|-------------|------------------|-----------------------------------------------------|
| Mainstreaming Disaster Risk Reduction | BNPB | - Mainstreaming in development plans  
- Monitoring, evaluation and updating of RENAS PB in an integrated manner with related sectors |
| Identification and Control of Vulnerability and Risk Factors in Public Health and the Environment | BAPPENA, MoEF, BIG | - Applied clinical research and development and clinical epidermology  
- Processing of health data and information |
| Improved emergency response system related to the dangers of climate change | LIPI, BPPT, MHA, BNPB, KOMINFO | - Health Crisis Management  
- continuous monitoring and data collection activities regarding the symptoms of outbreaks of infectious and non-communicable diseases caused by climate change  
- The formation of a response plan for health care  
- Achieving information to the public about outbreaks of infectious diseases caused by climate change |
| Strengthening regulations, laws and regulations, and institutional capacity at the central and local levels against risks to public health that can be caused by climate change | BNPB, MPWH, BAPPENAS, MHA | - Preparation of documents (legal products) related to climate change adaptation strategies in the health sector  
- Establishment of norms, standards, regulations and criteria regarding housing health and environmental sanitation  
- Formation of action plans and roadmaps for climate change adaptation in the health sector based on strategic zoning of climate change risk assessment results until 2050 in districts/cities  
- Coordination of the division of tasks, authorities, and resources between the central and regional governments  
- Increasing institutional capacity in the health sector in dealing with outbreaks of infectious and non-communicable diseases caused by climate change  
- Created increased partnerships and networks |

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