Resilience: A new concepts in dealing with hydro-meteorological disaster and it’s application at the provincial level in Indonesia

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Abstract. Resilience is more capable of dealing with hydro-meteorological disasters compared to the risk. Resilience is a positive concept that puts forward adaptation efforts so that more in line with sustainable development goals. This study aims to introduce the resilience concept in dealing with hydro-meteorological disasters and apply it at the provincial level in Indonesia. The methods used are: 1) measuring the climate risk index (CRI), 2) measuring the adaptation capacity index (ACI), and 3) classifying the provinces based on CRI and ACI. Grouping CRI and ACI are used to define provinces which have the potential to bounce back better (low CRI - high ACI), bounce back (high CRI – high ACI), recover but worse than before (low CRI - low ACI), and collapse (high CRI – low ACI). The study results indicate that throughout 2017 there are 10 provinces that South Sumatra, Central Java, and West Nusa Tenggara. In contrast, 3 provinces with the most have the potential to bounce back better, 7 provinces bounce back, 7 provinces recover but worse than before, and 10 provinces collapse. In general, 3 provinces with the lowest resilience are resilient levels are Riau, Bangka Belitung, and Riau Islands.

1. Introduction
The study of the resilience of disasters caused by climate change and extreme weather (hydro-meteorology) has not been as popular as risk studies. In fact, there is no consensus on how to measure resilience, so that it remains a challenge for researchers [1]. The change in the focus of research from risk to resilience is based more on the meaning of resilience, which prioritizes adaptation efforts so that it can be integrated with sustainable development goals [2]. Moreover, the nature of climate change tends to be a change for the worse and the point of no return so that the concept of resilience is seen as more capable in dealing with hydro-meteorological disasters in the future.

The basic principle of the concept of risk (R) is to emphasize the reduction of probability (P) and consequences (C) if a dangerous event occurs so that $R = P \times C$. While the concept of resilience emphasizes the ability to maintain the critical function of the system by absorbing disturbance, adaptation, and recovery. At risk, the hazard must be identified so that the consequences can be estimated; if the hazard is not known, risk analysis is not possible [3]. Conversely, the concept of resilience remains relevant and can be applied when the source of hazard is unknown, unpredictable, systemic, even catastrophic [3, 4]. Resilience does not have to be related to hazard, but if the hazard is known and predicted, efforts to build resilience become more directed and effective.
Indonesia is one of the countries prone to disasters, both disasters caused by geological activities or climate-related or hydro-meteorological disasters. On a national scale, hydro-meteorological disasters triggered by climate change and extreme weather are the most dominant, even for a period of 30 years (1989-2018), the percentage of occurrence of more than 98% [5]. For the Indonesian context, hydro-meteorological disasters include floods, landslides, tidal waves, whirlwinds, and droughts [5].

Efforts to increase resilience can be achieved by reducing vulnerability and increasing adaptive capacity [6]. In a broader scope, resilience can be understood as the ability of a social-ecological system to deal with shocks and pressures [7]. In the provincial context, resilience, besides being an indicator of success in development, can be used as a basis for the central government in prioritizing development in provinces with less resilience. This study aims to introduce the concept of resilience in the face of hydro-meteorological disasters and apply it at the provincial level in Indonesia.

### 2. Conceptual framework

#### 2.1. Resilience: a risk management approach

There is a link between risk assessment and resilience. In the context of risk, resilience can be seen as a complement and alternative to conventional risk management [4]. In this study, the second view is used; namely, resilience is used as an alternative to risk assessment. A comparison of the concept of risk and resilience [8] aligns the vulnerability of risk studies with intrinsic resilience in the study of resilience (Figure 1), resulting in its consequences (methods) when applied to discussions about resilience related to climate change. In climate studies, vulnerability is composed of sensitivity and adaptive capacity [9] so that intrinsic resilience must also be viewed in terms of sensitivity and adaptive capacity.

![Figure 1. Comparison of the concepts of risk and resilience [9]](image)

Risk is a function of vulnerability, exposure, and hazard; while resilience is a function of intrinsic resilience, exposure, and hazard. A comparison between the function risk and resilience only to show each variable or constituent, is not a relation between the two. The emergence of hazards can be used in measuring risk and resilience, hazard contributing positively to the level of risk. In contrast to resilience, hazard contributes negatively so that it can reduce the level of resilience. Likewise, with exposure and vulnerability, both increase the level of risk. In contrast to resilience, vulnerability decreases resilience, but intrinsic resilience can increase resilience. The hazards that have interacted with exposure turn into disasters so the resilience level is largely determined by intrinsic resilience. Intrinsic resilience is a condition of existing system resilience, which is strongly influenced by incremental adaptation capacity and transformational adaptation capacity in restoring the system to its original condition.
2.2. Element of resilience

Efforts to build climate resilience can be initiated from activities that can reduce risk or impact. Mathematically, the risk of climate change and extreme weather can be minimized through efforts to reduce the magnitude of the hazard, reduce exposure, and reduce vulnerability [10]. In fact, the sources of hazard are more difficult to reduce because they must be done through mitigation efforts that require expensive costs; one of the more realistic efforts is through adaptation. The concept of resilience places more emphasis on the ability to adapt. Still, if a hazard arises, the resilience that has been built is disrupted. The potential to return to its original state is largely determined by adaptive capacity, both incremental and transformational [9].

![Figure 2. Four elements of resilience [11]](image)

As with climate studies devoted explicitly to vulnerability, the study of resilience can also be devoted to "resilience of what to what" [12]. Consequently, if it only focuses on certain resilience, it can cause the system to lose resilience in other sectors. Therefore, strengthening resilience can be said as "about coping with uncertainty in all ways" [13]. In this case, what is meant by "resilience of what?" is climate resilience in the provincial context, while "resilience to what?" is the resilience of hydro-meteorological hazards. The hazard that has interacted with exposure and sensitivity turns into disasters so that they can be measured based on the climate risk index (CRI). In contrast, the ability to adapt is measured using the adaptation capacity index (ACI). Furthermore, the final results can be in the form of bounce back better, bounce back, recover but worse than before, or collapse (Figure 2).

3. Method

To understand the disturbances caused by climate change and extreme weather can be explained through risk indices such as those used to measure the Global Climate Risk Index [14]. The risk index is measured based on the level of losses from the social and economic dimensions, each of which has the same weight (50% : 50%). Furthermore, to determine the level of risk and capacity of the system in response to hydro-meteorological hazards, a modified framework has been used from the Department For International Development (DFID) United Kingdom in "Disaster Resilience Research: A DFID Approach Paper" [11]. The system’s ability to respond to hazard sources is largely determined by incremental adaptation and transformational adaptation which are illustrated through the adaptation capacity index. A resilient system will have a faster ability to recover to its original state than a less resilient system.
3.1. Data collection

Hydro-meteorological disaster data was obtained from the Indonesian Disaster Data and Information (DIBI), which can be accessed at http://dibi.bnpb.go.id. DIBI stores data on Indonesia’s disaster events and is managed by the National Disaster Management Agency (BNPB). Data on the number of hydro-meteorological disasters collected include floods, landslides, tidal waves, whirlwinds, and droughts. In contrast, the impact of the hydro-meteorological disaster includes: the number of deaths and damage to houses at a massive level. Further indicators to describe adaptive capacity were obtained from the Central Bureau of Statistics [15].

3.2. CRI measurement

CRI is measured based on two social indicators and two economic indicators, including 1) the number of deaths, 2) the number of deaths per 100,000 inhabitants, 3) the sum of losses in the US$ in purchasing power parity, and 4) losses per unit of Gross Domestic Product (GDP). While for the weight of each indicator: mortality = 1/6; mortality rate per 100,000 population = 1/3; total loss = 1/6; and losses per unit of GDP = 1/3. In this study, to calculate CRI scores in each province, modifications were made to two economic indicators using the number of house damage and damage per 25,000 houses. Furthermore, CRI is calculated based on ranking from each province according to the number of deaths and the level of damage to the house.

For example, the CRI score of Aceh in 2017:
- Ranked 11th in the number of deaths.
- Ranked 15th deaths per 100,000 inhabitants.
- Ranked 7th in total damage to the house at the weight level.
- Ranked 5th damage to houses per 25,000 houses.

Calculation of CRI score:

\[ \text{CRI} = (11 \times \frac{1}{6}) + (15 \times \frac{1}{3}) + (7 \times \frac{1}{6}) + (5 \times \frac{1}{3}) = 9.67 \] (1)

Ranked 11th in the death toll indicates that Aceh has the highest number of casualties in number 11 compared to 33 other provinces, as well as the other three ranks. On the contrary, the final result in determining the CRI rank is that the smallest value is the province that ranks first in terms of the climate risk level. In this example, Aceh was ranked 7th in 2017.

3.3. ACI measurement

ACI is the sum of the incremental adaptation index \(I_AI\) and the transformational adaptation index \(T_AI\). ACI measurements are carried out through stages:
- Determination of key indicators based on the definition of incremental adaptation and transformational adaptation in the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change [9].
- The weighting of indicators is done by the ranking method [16].
- Test the data’s normality to get scaling of each indicator and divided into five scales based on the average value and standard deviation [17].

To produce a single index, the various indicators are standardized to be the same unit [18]. Furthermore, \(I_AI\) and \(T_AI\) are extracted based on the equation:

\[ \text{Index} = \text{Weight} \times \text{Scale} \] (2)

\[ \text{ACI} = I_AI + T_AI \] (3)

3.4. Grouping of CRI and ACI scores

Each CRI and ACI score are grouped into two categories, namely: high and low, based on the average value or ranking. At CRI it is categorized as high if it has a score below average and a low category if above average. Meanwhile, the ACI is categorized as high if it has a score above the average and a
low category if it is below the average. The grouping based on CRI and ACI scores was used to map provinces into four categories: low CRI - high ACI, high CRI – high ACI, low CRI - low ACI, and high CRI – low ACI.

4. Results and discussion

4.1. CRI rank per province

The CRI score calculation results in 2017 (Table 1) show that the average CRI for 34 provinces is 16.17 (Table 1). There are 18 provinces that have CRI scores below the average, while 16 other provinces have CRI scores above the average. Provinces with a CRI score below the average have a high-risk level, indicating casualties and economic losses. On the other hand, provinces with a CRI score above the average have a low level of risk, both in terms of the number of victims who died and house damage (an economic loss). Two provinces have the same CRI score (25.00), namely Jambi and West Kalimantan. There are three provinces with a 1-3 rank: East Java, Papua, and Central Sulawesi.

That is, the three provinces were most affected by the hydro-meteorological disaster throughout 2017 with the highest number of dead and damaged houses. In contrast, the three least affected provinces were West Papua, Riau Islands, and Jakarta SCR.

| CRI Rank | Province            | CRI Score | Number of death per 100,000 inhabitants | Number of death severely damaged | The house was severely damaged | Damage per 25,000 houses |
|----------|---------------------|-----------|----------------------------------------|----------------------------------|-------------------------------|------------------------|
| 7        | Aceh                | 9.67      | 11                                     | 0.140                            | 15                            | 5.499                  |
| 11       | North Sumatra       | 11.33     | 6                                      | 0.115                            | 16                            | 2.456                  |
| 15       | West Sumatra        | 13.33     | 8                                      | 0.212                            | 8                             | 1.721                  |
| 24       | Riau                | 21.00     | 5                                      | 0.079                            | 21                            | 0.558                  |
| 29       | Jambi               | 25.00     | 2                                      | 0.059                            | 25                            | 0.384                  |
| 14       | South Sumatra       | 13.17     | 7                                      | 0.087                            | 18                            | 2.501                  |
| 27       | Bengkulu            | 24.00     | 0                                      | 0.000                            | 29                            | 0.846                  |
| 18       | Lampung             | 16.00     | 2                                      | 0.025                            | 26                            | 2.536                  |
| 30       | Bangka Belitung     | 25.50     | 1                                      | 0.073                            | 22                            | 0.215                  |
| 32       | Riau Islands        | 26.17     | 0                                      | 0.000                            | 29                            | 0.480                  |
| 31       | Jakarta SCR         | 26.00     | 7                                      | 0.069                            | 23                            | 0.009                  |
| 16       | West Java           | 15.17     | 3                                      | 0.069                            | 24                            | 1.740                  |
| 5        | Central Java        | 9.50      | 52                                     | 0.172                            | 11                            | 2.096                  |
| 20       | Yogyakarta SR       | 16.83     | 14                                     | 0.381                            | 4                             | 0.294                  |
| 1        | East Java           | 3.00      | 105                                    | 0.270                            | 5                             | 5.815                  |
| 26       | Banten              | 23.00     | 1                                      | 0.008                            | 28                            | 0.691                  |
| 6        | Bali                | 9.50      | 18                                     | 0.433                            | 3                             | 2.001                  |
| 13       | West Nusa Tenggara | 12.33     | 10                                     | 0.207                            | 9                             | 1.711                  |
| 4        | East Nusa Tenggara | 7.33      | 8                                      | 0.156                            | 13                            | 4.127                  |
| 29       | West Kalimantan     | 25.00     | 1                                      | 0.021                            | 27                            | 0.426                  |
| 28       | Central Kalimantan  | 24.83     | 2                                      | 0.080                            | 20                            | 0.155                  |
| 23       | South Kalimantan    | 19.67     | 0                                      | 0.000                            | 29                            | 2.098                  |
| 19       | East Kalimantan     | 16.67     | 6                                      | 0.176                            | 10                            | 0.733                  |
| 21       | North Kalimantan    | 17.83     | 1                                      | 0.145                            | 14                            | 2.249                  |
| 12       | North Sulawesi      | 12.17     | 2                                      | 0.083                            | 19                            | 5.832                  |
| 3        | Central Sulawesi    | 7.17      | 16                                     | 0.556                            | 1                             | 2.952                  |
| 8        | South Sulawesi      | 9.83      | 15                                     | 0.176                            | 10                            | 2.594                  |
| 10       | Southeast Sulawesi  | 10.67     | 4                                      | 0.160                            | 12                            | 4.400                  |
| 25       | Gorontalo           | 21.83     | 1                                      | 0.088                            | 17                            | 0.564                  |
| 22       | West Sulawesi       | 17.83     | 0                                      | 0.000                            | 29                            | 4.453                  |
| 17       | Maluku              | 15.83     | 4                                      | 0.237                            | 7                             | 1.074                  |
| 9        | North Maluku        | 10.50     | 3                                      | 0.258                            | 6                             | 4.581                  |
| 33       | West Papua          | 28.83     | 0                                      | 0.000                            | 29                            | 0.130                  |
| 2        | Papua               | 3.17      | 14                                     | 0.445                            | 2                             | 10.38                  |

| Average CRI Score | 16.17 |

| 4.2. ACI rank per province |

There are 10 indicators used to measure incremental adaptation, and there are 4 indicators that have a high weight, namely: Regional income for the environment (%), Human Development Index, Gini Ratio, and Workforce participation rate (%). Furthermore, of the 8 indicators on transformational adaptation, 4 indicators have high weight: the proportion of individuals who access the internet, the proportion of individuals who read newspapers/books, rural residents who use cell phones, and the
involvement of women in parliament. Thus, provinces with a high score (scale) on these indicators will have a high incremental adaptation index and a transformational adaptation index.

### Table 2. The weight and scale of each indicator

| No | INDICATORS | Weight | Scale |
|----|------------|--------|-------|
| 1  | Gross regional domestic product per capita (thousand Indonesian rupiah) | 0.072 | <13.39 | 21.11 - 28.84 |
| 2  | Gini Ratio | 0.154 | >0.404 | 0.368 - 0.404 |
| 3  | The ratio of active cooperatives per 1000 inhabitants | 0.092 | >0.28 | 0.28 - 0.5 |
| 4  | Human Development Index | 0.189 | >60.59 | 60.59 - 65.3 |
| 5  | Workforce participation rate (%) | 0.115 | 61.92 - 65.21 | 65.22 - 68.5 |
| 6  | Level of satisfaction with 10 aspects of life (%) | 0.025 | <66.65 | 66.65 - 69.4 |
| 7  | Regional income for the environment (%) | 0.376 | <0.11 | 0.11 - 0.30 |
| 8  | Households served by electricity (%) | 0.031 | <69.46 | 69.46 - 82.54 |
| 9  | The ratio of road length to area | 0.052 | <0.03 | 0.03 - 0.27 |
| 10 | The ratio of the number of hospital beds per 1000 inhabitants | 0.039 | >62 | 62 - 118 |

### Table 3. Adaptive capacity index (ACI) 2017

| No | Province | Index | ACI Rank |
|----|----------|-------|----------|
| 1  | Aceh     | 3.204 | 3.742 | 3.473 | 16 |
| 2  | North Sumatra | 3.936 | 3.236 | 3.586 | 11 |
| 3  | West Sumatra | 3.961 | 3.271 | 3.616 | 8 |
| 4  | Riau     | 3.069 | 4.214 | 3.642 | 7 |
| 5  | Jambi    | 3.212 | 3.186 | 3.199 | 26 |
| 6  | South Sumatra | 2.831 | 3.370 | 3.101 | 27 |
| 7  | Bengkulu | 3.815 | 3.104 | 3.460 | 18 |
| 8  | Lampung | 2.684 | 3.083 | 2.884 | 31 |
| 9  | Bangka Belitung | 3.835 | 3.622 | 3.729 | 6 |
| 10 | Riau Islands | 3.471 | 3.658 | 3.565 | 13 |
| 11 | Jakarta SCR | 3.883 | 4.769 | 4.326 | 1 |
| 12 | West Java | 3.261 | 3.941 | 3.571 | 12 |
| 13 | Central Java | 3.026 | 3.461 | 3.244 | 25 |
| 14 | Yogyakarta SR | 3.905 | 4.128 | 4.017 | 4 |
| 15 | East Java | 3.400 | 3.574 | 3.487 | 15 |
| 16 | Banten  | 2.968 | 3.975 | 3.472 | 17 |
| 17 | Bali     | 3.967 | 4.207 | 4.087 | 3 |

The I\_A\_1 and T\_A\_1 values in a province are obtained from the total multiplication results between the weights and the scale of each indicator (Table 2), while the ACI is the sum of the I\_A\_1 and T\_A\_1 scores (Table 3). The results of ACI calculations show that three provinces have 1-3 rank, namely: Jakarta SCR, East Kalimantan, and Bali. That is, the three provinces have the highest adaptation capacity (incremental and transformational). In other words, it has the fastest potential in restoring the system to its original condition. In contrast, the three provinces that are the slowest in carrying out recovery are East Nusa Tenggara, West Nusa Tenggara, and Papua.
4.3. Provincial grouping based on CRI and ACI scores

From the results of the CRI grouping, provinces with high climate risk spread evenly across Java, Sumatra, Sulawesi, and Nusa Tenggara; as well as low climate risk, it is not only concentrated on one island. This suggests that the threat of hydro-meteorological disasters triggered by climate change and extreme weather spread throughout Indonesia’s territory. On the other hand, the high impact of disasters triggered by climate is largely determined by exposure conditions and the level of sensitivity of the existing social-ecological system. The magnitude of the impact is largely determined by incremental and transformational adaptation in each province.

Table 4. Provincial grouping based on CRI and ACI score

| Climate Risk Index (CRI) | Adaptive Capacity Index (ACI) |
|-------------------------|-----------------------------|
| Low                     | Aceh                        |
| South Sumatera          | North Sumatera              |
| Central Java            | West Sumatera               |
| East Nusa Tenggara      | West Java                   |
| South Sulawesi          | East Java                   |
| Central Sulawesi        | Bali                        |
| Southeast Sulawesi      | North Sulawesi              |
| Maluku                  |                              |
| North Maluku            |                              |
| Papua                   |                              |
| Jambi                   | Riau                        |
| Bengkulu                | Bangka Belitung             |
| Lampung                 | Riau Islands                |
| West Kalimantan         | Jakarta SCR                 |
| Gorontalo               | Yogyakarta SR               |
| West Sulawesi           | Banten                      |
| West Papua              | Central Kalimantan          |
| Low                     | South Kalimantan            |
| Low                     | East Kalimantan             |
| High                    | North Kalimantan            |

To compare the level of risk and adaptation capacity, grouping CRI and ACI scores into two groups: above average and below average. The two CRI groups and two ACI groups were grouped again into four categories, namely: low CRI - high ACI, high CRI – high ACI, low CRI - low ACI, and high CRI – low ACI. In 2017 South Sumatera had the highest risk - the lowest adaptive capacity, and North Kalimantan has the lowest risk - the highest adaptive capacity (Table 4). This condition in the future may change; provinces that currently have high risk and low adaptive capacity cannot guarantee that these conditions will continue.

Disasters that occur in a province are temporary, meaning they do not continue for a period of one year; on the contrary, adaptation capacity is a capability that has been formed. However, grouping provinces into four categories based on CRI and ACI scores can be used as an indicator of their potential outcome from disturbances, with the following criteria:

- Low CRI - high ACI : bounce back better.
- High CRI – high ACI : bounce back.
- Low CRI - low ACI : recover but worse than before.
- High CRI – low ACI : collapse.

5. Conclusion

Resilience brings a positive narrative and prioritizes efforts to improve adaptive capacity so that it is aligned with sustainable development goals. To describe resilience in a province can be measured based on CRI and ACI scores. The smaller CRI score shows the worse the impact of hydro-meteorological disasters; on the contrary, the higher ACI indicates better adaptive capacity. Grouping
CRI and ACI score can be used as a reference to determine provinces that have the potential to bounce back better (low CRI - high ACI), bounce back (high CRI – high ACI), recover but worse than before (low CRI - low ACI), and collapse (high CRI – low ACI).

The results of the study indicate that throughout 2017 there are 10 provinces that potentially bounce back better, 7 provinces bounce back, 7 provinces recover but worse than before, and 10 provinces that potential to collapse. In general, 3 provinces that have the lowest resilience are South Sumatra, Central Java, and West Nusa Tenggara. In contrast, 3 provinces with the most resilient levels are Riau, Bangka Belitung and Riau Islands. The grouping can be used by the central government to prioritize development in provinces that have less resilient.

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