Identification of climate change impact at Raknamo Dam, Kupang, Indonesia

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Abstract. Impacts of climate change have received extensive attention, especially for the semi-arid regions. Raknamo reservoir is located at Kupang Regency, a semi-arid area with significant differences in rainy duration (3–4 months) and dry seasons (8–9 months). This preliminary study aimed to identify the recent factors that caused the delays in initial filling of Raknamo reservoir, which may be affected by climate change. There are three rainfall stations observed surrounding Raknamo watershed, namely Camplong, Naibonat and Raknamo. Direct comparisons were made of rainfall data for 33 years (1986–2019) daily. The climatology station Lasiana was used for climatological data with a data length of 33 years (1986–2019). This research used a qualitative approach, runoff was analyzed using regression analysis. The results showed that factors such as temperature (T), potential evapotranspiration (ETO), and rainfall (R) affected the availability of initial filling in the Raknamo reservoir. The amount of rainfall intensity that is not achieved in one period to fill the reservoir has resulted in the Raknamo reservoir utilization not being optimized.

1. Introduction
Raknamo dam is located at Noel Puentes river, lays at 10° 07’ 08” S and 123°55’ 54” E, about 9 km from Amabi-Oefeto sub-regency, Kupang regency, East Nusa Tenggara (NTT) Province, at 33 km Northeast of Kupang city (see Figure 1). The dam was built to fulfill water demand for irrigation of 1250 Ha, and domestic water for Kupang City at about 100 l/s. Raknamo dam covers a length of 15.71 km from the upstream to the dam's point and an area of 38.34 km² of catchment area [1]. According to Koppen, Raknamo dam is included in areas with a semi-arid climate where there is a very striking difference between the rainy and dry seasons. The rainy season occurs within 3-4 months and the dry season 8-9 months. The average annual rainfall is ± 1,287 mm/year [2]. East Nusa Tenggara is located in the southern part of Indonesia, which has decreased rainfall, it greatly affects water resources management for various demands. Research on water resources in other semi-arid regions of the world has been carried out in a wider area. Raknamo dam construction was completed in the end of 2017 and is scheduled to be initial filling (impounding) in 2018. However, up to three rainy periods (2018-2020), this dam was not full and could not be used optimally. Raknamo dam has not been optimal due to several factors, including natural conditions and climate change in NTT.
According to Masih et al [3], in semi-arid areas with high discharge variability between rainy and dry seasons, it is challenging to fulfill multi-sector water demands throughout the season, especially during dry season. One of the main problems is related to reservoir operation. For this reason, adaptive reservoir management to local climatic conditions and global climate change threat is necessary [4]. The semi-arid climate is an area climate that receives lower rainfall than potential evapotranspiration and this semi-arid region covers 31% of the world area [5]. Montenegro and Ragab [6] stated that semi-arid areas have rainfall frequency below average and are erratic, so often caused drought.

![Figure 1. Location of Raknamo Reservoir](image)

Climate change occurrence greatly affects management and operating patterns of water infrastructures such as irrigation systems and water supply systems. This situation will be even more complicated if the natural resource management system’s characteristics and policies are insufficient to mitigate this change. Irrigation methods and water management practices will also be affected. The main water resource for agriculture comes from the base flow in rivers (for dry periods), affecting groundwater recharge (effect on long-term aquifers). The effects of climate change will also affect efforts to manage natural resources. Global warming results in climate change and increases the frequency and intensity of extreme weather events. Intergovernmental Panel on Climate Change (IPCC) 1992, states that global warming can cause significant changes, including precipitation patterns and wind patterns. The use of water in connection with efforts to anticipate climate change is necessary to manage and use water during rainy season and dry season, for example, regulation of reservoir operation patterns.

Zu and Ringler [7] analyzed climate change effects on water availability and use in Limpopo watershed (South Africa) using a semi-distributed global hydrological model system, Water Simulation Module (WSM) of International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT). The analysis aims to obtain projections of water resources' availability from the Limpopo watershed until 2050 by improving water infrastructure and management interventions. Soewarno [8] also examined climate change effects and non-climate factors on agricultural production in Nigeria. Kaczmarek et al [9] conducted a similar study on Warta watershed in Poland using two scenario models, namely warm-dry scenario with Geophysical Fluid Dynamics Laboratory (GFDL) model and scenario for dry season with Goddard Institute for Space Studies (GISS). The results obtained indicate that water
demands fulfillment and availability in Warta watershed is strongly influenced by climate change. Adaptation options become recommendations for addressing water degradation needs due to climate change effects. Changchun et al [10] examined the relationship between rainfall, temperature, surface runoff, flood frequency and peak flow in eight rivers in Xinjiang, China. The study found that climatic conditions in almost all Xinjiang regions have experienced increasing temperature and rainfall intensity since 1980. This contributed to the increased surface runoff on rivers in Xinjiang since 1990. Global warming impacts on regional hydrological cycles. This study aimed to identify climate change's impact on Raknamo dam operations. Identification was carried out descriptively through climate change influence factors in the Raknamo dam.

2. Materials and methods
This research used a qualitative approach to study and identify climate change impacts on Raknamo dam operations' implementation plans in semi-arid areas. The study was carried out on changes in the hydrological regime and climate variability in the study area. Analysis of changes in the hydrological regime is mainly carried out on rain and discharge parameters as the hydrological cycle's main components. Analysis of climate variability was carried out on climatic parameters, namely: temperature, humidity, duration of sun exposure, wind speed and potential evapotranspiration. The variables in the model are time series, and it is necessary to test the order of stationarity. The data processing and analysis, in general, is carried out as follows:

- Evaluation of secondary data feasibility, the data were rainfall, climate and observation discharge data. Rainfall data were analyzed statistically for consistency test, homogeneity test [11][12][13] and feasibility of the number of stations and data length according to requirements.
- Rainfall data completion (daily, monthly and annual rainfall) was done using normal comparison method. This method was chosen because it is following the characteristics of the rainfall data.
- Consistency of rainfall data was tested on rainfall data equipped with mass curve analysis and Rescaled Adjusted Partial Sums (RAPS). These methods are standard methods in testing the consistency of hydrological data [11][12][13].
- Homogeneity test was carried out to determine whether the data series collected from two measuring stations located in one watershed or one outside e watershed originate from same population or not. The method used to test homogeneity after paired t-test was a statistical method to test two groups of the same data.
- Calculation of regional rainfall. Average rainfall values were searched using arithmetic mean method, inverse distance method and IDPT hybrid method [11][14][13]. Arithmetic method was the simplest model in calculating regional rain which was done by calculating arithmetic mean. Inverse distance method considered distance effect of rainfall station on regional rainfall.

3. Results and discussion
The results of monthly climatology data Raknamo dam (1986-2019) are shown in Table 1. Monthly average temperature in Kupang regency, especially Raknamo catchment area has the highest temperatures in October and November, with temperatures reaching over 28°C. The lowest rainfall occurs in August with an average of 2.25 mm and dry season’s peak is in the middle year. This can bring government attention in utilizing rainy months, which only lasts 3-4 months, to harvest rainfall water for dry season. Temperature, potential evapotranspiration, and precipitation time series in recent 36 years in the Raknamo catchment area showed in Table 2.

The mean annual temperature and potential evapotranspiration appeared a significant increasing trend (Figure 2 and Figure 3). Annual evapotranspiration was obtained from calculations using Penman modification and the results are shown in Figure 3.
Table 1. The average of monthly climatic data in Raknamo catchment area (1986-2019)

| Parameter                  | Month          |
|----------------------------|----------------|
| Min temperature (°C)       | Jan Feb Mar Apr May June July August Sep Oct Nov Dec | 24.43 24.16 23.67 23.50 23.44 22.43 21.95 21.55 21.94 23.59 24.53 24.64 | 24.30 24.04 23.56 23.49 23.43 22.43 21.95 21.55 21.94 23.59 24.53 24.64 |
| Max temperature (°C)       |                | 30.59 30.40 31.06 32.51 32.73 31.76 31.81 32.09 32.73 33.30 33.04 31.53 |                |
| Average temperature (°C)  |                | 27.34 27.10 26.97 27.49 27.40 26.44 26.02 26.03 26.98 28.43 29.00 28.10 |                |
| Solar radiation (%)        |                | 53.05 56.74 68.15 82.09 89.74 89.06 91.53 95.03 95.50 92.33 79.59 60.35 |                |
| Wind speed (m/detik)       |                | 2.73 2.50 2.22 2.63 3.45 4.31 4.31 4.32 3.78 3.41 3.02 2.50 |                |
| Humidity (%)               |                | 85.65 85.58 85.49 79.18 73.91 71.12 68.29 66.44 66.89 69.99 74.86 81.89 |                |
| Rainfall (mm)              |                | 406.63 378.09 252.72 82.31 12.52 8.08 2.25 9.89 25.02 100.00 271.49 |                |
| Evaporation (mm)           |                | 139.04 129.69 146.13 157.23 177.64 168.39 191.54 214.99 213.61 220.79 192.02 154.28 |                |

Table 2. The temperature and annual rainfall data of Raknamo catchment area (1986-2019)

| Year | Temperature (°C) | Annual rainfall (mm) | Year | Temperature (°C) | Annual rainfall (mm) |
|------|------------------|----------------------|------|------------------|----------------------|
| 1986 | 27.38            | 1169.00              | 2003 | 27.41            | 2382.40              |
| 1987 | 27.43            | 1542.00              | 2004 | 27.36            | 1272.00              |
| 1988 | 27.57            | 1538.00              | 2005 | 27.50            | 1296.00              |
| 1989 | 27.02            | 1143.00              | 2006 | 27.19            | 1743.00              |
| 1990 | 27.06            | 1247.00              | 2007 | 27.39            | 1291.00              |
| 1991 | 26.66            | 1617.00              | 2008 | 27.08            | 1999.00              |
| 1992 | 27.13            | 1131.00              | 2009 | 27.40            | 1919.00              |
| 1993 | 27.09            | 1375.00              | 2010 | 27.83            | 1595.00              |
| 1994 | 26.82            | 1330.00              | 2011 | 26.98            | 1699.00              |
| 1995 | 26.92            | 2133.00              | 2012 | 27.25            | 1211.00              |
| 1996 | 26.98            | 2428.00              | 2013 | 27.53            | 1915.00              |
| 1997 | 26.57            | 1471.00              | 2014 | 27.38            | 1404.00              |
| 1998 | 27.62            | 1425.00              | 2015 | 27.48            | 1406.00              |
| 1999 | 26.78            | 2140.00              | 2016 | 28.38            | 960.00               |
| 2000 | 26.93            | 2101.00              | 2017 | 27.51            | 1552.40              |
| 2001 | 27.27            | 1520.00              | 2018 | 27.59            | 1372.60              |
| 2002 | 27.49            | 1301.00              | 2019 | 27.38            | 1015.00              |

Figure 2. The mean annual temperature (1986–2019)
Figure 3. The mean annual potential evapotranspiration (1986–2019)

Figure 4. The annual rainfall (1986–2019)

Figure 5. The average temperature and annual rainfall for 33 years in Kupang District

The annual precipitation showed a decreasing trend over the last 33 years (Figure 4). Increasing temperature and potential evapotranspiration need to be studied more deeply concerning the amount of annual rainfall in Kupang regency.
Temperature series jumped in 1998 and potential evapotranspiration series increased in about 2002 (Figure 3). Mean annual temperature was 27.05 °C in 1986–1997 then increased to 27.38 °C in 1998-2019. Precipitation also tended to decrease 0.34% obviously in Kupang regency.

The results showed an increase in temperature and a decrease in annual rainfall can impact the runoff entering the Raknamo dam. This research was a preliminary study in identifying input data in the runoff analysis for 36 years in Raknamo area. In future studies, uncertainty should be considered in all downscaling processes. Finally, climate change in the semi-arid region has a decreasing trend impact on basin runoff; in some years, river flow has been decreased but through more accurate study such as simulations, climate change impact on drought extreme occurrences become much clearer. Thus, assessing various approaches to climate change adaptation is necessary and useful for the semi-arid region.

4. Conclusion
Climate and hydrologic modeling of climate change impact assessment on water resource availability, especially in the semi-arid region, are major challenges. Precipitation is the main parameter of variability in the water balance over space and time. Changes in precipitation have very important implications for hydrology and water resource. The rainfall-runoff change was closely related to climatic factors. The correlation analysis on temperature in Raknamo catchment area showed that decreased precipitation of Noel Puames river was closely related to temperature. Climate models reveal that precipitation will generally decrease over the semi-arid region by 0.34% per year at the regional scale. An increase in temperature and a decrease in annual rainfall can impact the runoff entering Raknamo dam.

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