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Identification, Mapping and Solutions for Drought Management in Kaliori District, Rembang Regency, Indonesia

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ABSTRACT

Rembang Regency is one of the regencies in Central Java that often experiences drought. Based on the results of the mapping of drought-prone areas for 2020 carried out by the Rembang Regency government, there are 63 villages spread across 14 sub-districts, 18,885 families are recorded as experiencing drought. Kaliori District is one of the sub-districts in Rembang Regency that is affected by drought, this sub-district consists of 23 villages and is directly adjacent to the north of Java Sea. The purpose of this research is to be able to do a mapping for planning sustainable drought solutions, obtain quantitative data on drought and stages of drought management. The stages of the research carried out were site surveys and interviews related to drought in the Kaliori area. Prior to the Focus Group Discussion (FGD), a questionnaire was prepared. This research was conducted through joint FGD with all village heads in Kaliori District regarding water drought in Rembang. Based on the FGD and the statistical analysis results, it was found that 70% of Kaliori District experienced drought. When there is a drought, generally villages in Kaliori sub-district use water from water tanks and some use wells of poor quality and having a salty taste. The majority of villages in Kaliori Sub-district experienced a drought that lasted for 4-5 months of a year. Several parties involved in dealing with drought in Kaliori Sub-district included PAMSIMAS, Karang Taruna, Banser, Paguyuban, and P3A. Some solutions proposed are river connection, estuary river gate, and reservoir optimation.

1. Introduction

Drought is a state of shortage of water supply in an area for a prolonged period. The duration can vary from several months to years [1]. Drought occurs when an area experiences below-average rainfall continuously for several months to years. Usually, droughts are caused by dry seasons that last longer than usual. A drought that lasts too long will drain groundwater reserves in the region, either due to evaporation, transpiration, or continuous use by humans [2]. As a result, the residents' wells have dried up, and water sources have not flowed. Trees withered and many food crops died.

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This will ultimately have an impact on human life living in areas experiencing drought because water has a very vital role [3]. Although water is a renewable natural resource, the availability of clean water for the needs of present and future generations is uncertain [4].

In more detail, Law of The Republic of Indonesia Number 24 of 2007 concerning Disaster Management defines drought as the availability of water that is far below the need for water for living needs, agriculture, economic activities and the environment. What is meant by drought in agriculture is drought that occurs on agricultural land where there are crops (rice, corn, soybeans, etc.) that are being cultivated [5].

The land drought that occurred in Rembang Regency was increasingly widespread and resulted in a lack of water supply for the needs of raw water and irrigation water for residents of the surrounding community. According to the statement from the Head of Emergency and Logistics at the Rembang Regional Disaster Management Agency, the number of villages applying for additional clean water is increasing because it is predicted that the drought will last quite a long time [6][7].

This study conducted a spatial analysis of drought conditions and preventive action suggestions in Kaliori District, Rembang Regency. Through this analysis, it is hoped that the distribution of drought and the level of vulnerability and risk will be described so that this information can be used as input for policy making in an effort to develop plans to prevent drought or find water needs in planned areas.

2. Methodology

The location of this research was conducted in Kaliori District, Rembang Regency, Central Java Province with the research object being the availability of water sources, water needs, and residents of Kaliori District. Methods of data collection by observation, interviews, and documentation. This study uses primary data and secondary data. Primary data includes the condition survey of Kaliori Sub-District, Rembang Regency based on information from residents (drought duration, water source used, and parties involved). Secondary data includes spatial data in the form of thematic maps, statistical data that support research, and literature study. The analytical method used is descriptive analysis, comparative analysis, and map overlay analysis. Map overlay analysis is used to describe a map of the drought condition area in the study area.

3. Result and Discussion

3.1 Drought Disaster Study in Rembang Regency

Based on the 2010 Drought Disaster Risk Index Map by BNPB (National Disaster Management Agency) it is known that the Central Java Province area has a high risk of drought. The broad potential for drought hazard determines the index value and hazard class [8]. Areas in Central Java that are classified as high hazard classes have potential for drought according to the 2016-2020 Central Java Disaster Risk Study, including Wonogiri, Karanganyar, Sragen, Grobogan, Blora, and Rembang [9].

Rembang Regency is one of the regencies in Central Java which is included in the category of very prone to drought with a hazard potential of 88,713 Ha with a drought disaster risk index score of 12.10. One illustration of the drought in this region is that in the southern part of Rembang Regency there are the Sukolilo karst mountains which extend from west to east and stretch from Grobogan, Pati, Rembang and Blora. This area is defined in the Regulation of the Minister of Energy and Mineral Resources The Republic of Indonesia No. 17 of 2012 concerning the designation of the Karst Natural Landscape area, as a karst area. This area is also the largest water recharge area in Rembang district

known as the Watuputih mountains or the Watuputih Karst Region, which is the Watuputih Groundwater Basin (CAT) area as stipulated [10].

Morphological changes caused by changes in land use, mining, land degradation have the potential to result in loss of groundwater absorption function in this region [11]. With this change causing a degradation of the amount of water stored in the Watuputih Groundwater Basin, there is a change in the composition of the baseflow compared to the total flow. Based on epicarst theory, limestone hill mining will reduce the amount of diffuse water stored, and vice versa will increase the flow of conduits when it rains [12]. Loss of epicarst function will result in loss of water absorption function in the Watuputih Groundwater Basin area. With the loss of water reserves in the Watuputih Groundwater Basin, 4 million cubic meters of groundwater will be lost and will impact 14 sub-districts in Rembang district in the form of drought during the dry season. With an average water use of 15-20 liters/day/person in 14 sub-districts in Rembang district, with an estimate of meeting the water needs of 607,188 people, this will result in insufficient clean water needs in the community during the dry season. One of the affected areas of the reduced groundwater discharge is Kaliori District.

3.2 Drought Condition in Kaliori District

During observations and interviews with residents of Kaliori Subdistrict, it was discovered or known that Kaliori Subdistrict, which consists of 23 villages, 83% of which have experienced drought in the last 3 years. It has been shown in Figure 1 a diagram of the percentage of villages in Kaliori that experience drought

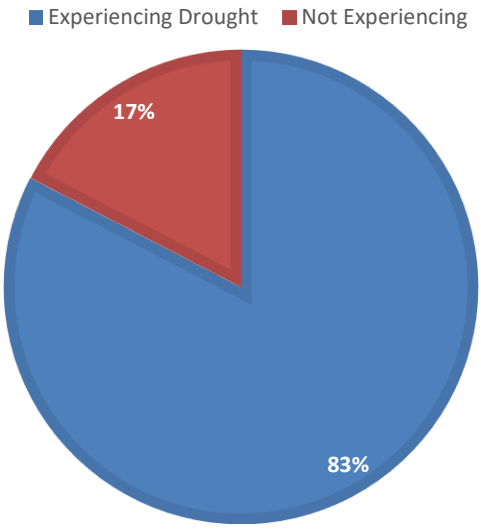

Fig. 1. Diagram of Areas Experiencing Drought in Kaliori District

In addition, the majority of droughts occur for 4-5 months by 52% as shown in Figure 2. The 12 villages experiencing drought for this period or duration are Tunggulsari Village, Mojowarno Village, Purworejo Village, Karangsekar Village, Bogoharjo Village, Sendangagung Village, Kuangsan Village, Sidomulyo Village, Wiroto Village, Meteseh Village, Banggi Village and Babadan Village. Based on the duration of the drought event at the research location, it appears that this location is experiencing

quite an intense drought so a solution is needed to minimize the risks experienced by residents due to drought events. Meanwhile, Kaliori District has handled the water dropping system.

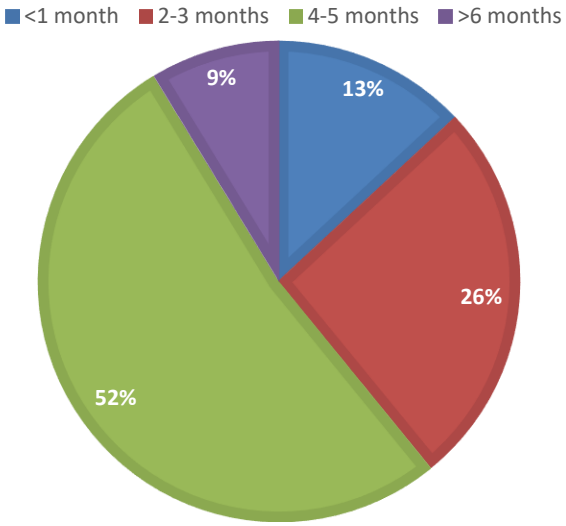

Fig. 2. Percentage of Drought Periods in Village Areas in Kaliori District

Dropping water is distributed by several agencies, such as the Rembang Regency Regional Disaster Management Agency, community organizations, and the village government. Kaliori Sub-District, on average, gets dropping water in 14 villages during a drought, including Tunggulsari Village, Tambakagung Village, Mojowarno Village, Dresi Kulon Village, Dresi Wetan Village, Tasikharjo Village, Purworejo Village, Karangsekar Village, Bogoharjo Village, Pantiharjo Village, Gunungsari Village, Kuangsan Village, Banggi Village, Sidomulyo Village. The spread of water distribution through a water dropping system using tank trucks is depicted in the map in Figure 3.

Residents of Kaliori District obtain water through several methods, including piped water, pumping it from private wells, dropping it from a water tanker truck, or transporting it privately. Moreover, water quality in Kaliori District is dominated by clear and odorless, but some others have a salty taste due to the use of groundwater near the sea coast so that sea water intrusion is possible. Salination of groundwater, surface water and soil resources also increases with land-based drought events, and decreasing river discharge in combination with water extraction and sea-level rise.

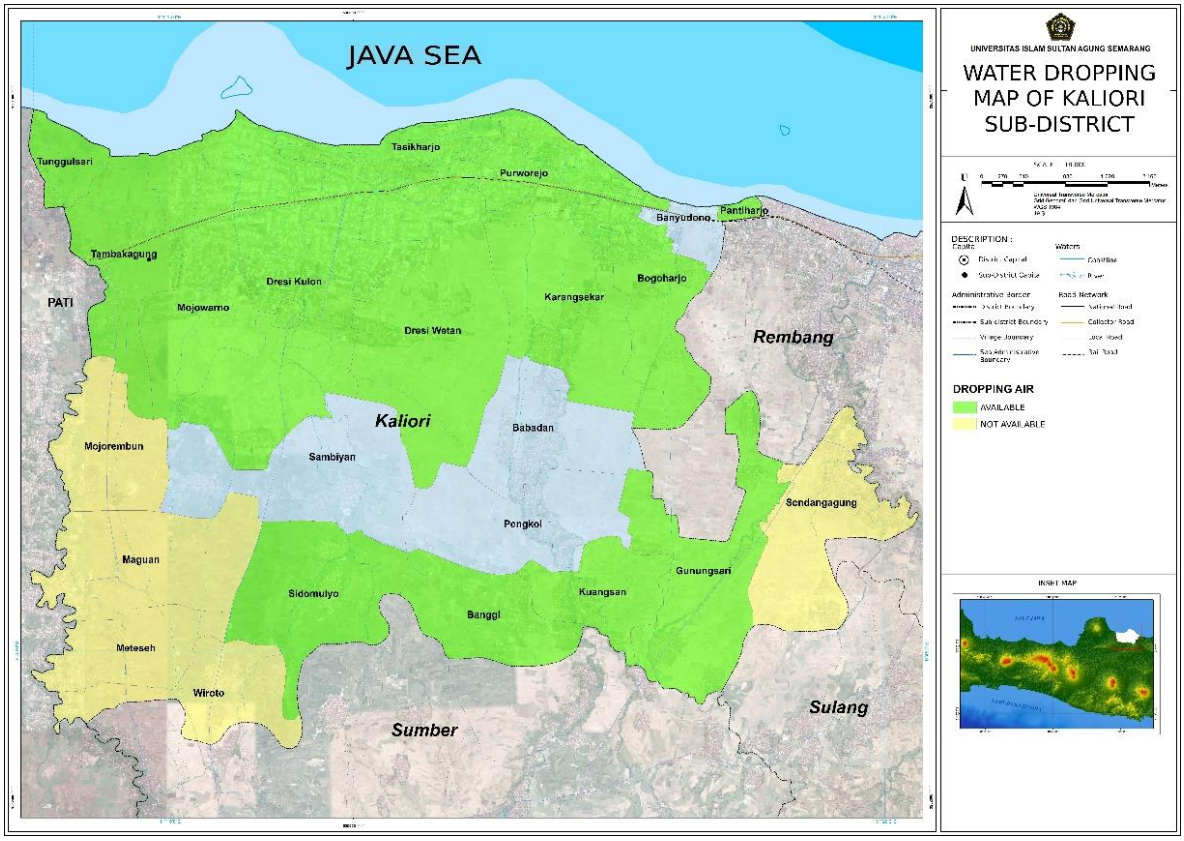

Fig. 3. Water Dropping Map in Kaliori Subdistrict

3.3 Drinking Water Demand in Kaliori Sub-district

The total population living in Kaliori District, Rembang Regency, until now is 42,590 people and will increase to 43,240 people in the next 2 years, 44,233 people in the next 5 years, and 45,940 people in the next 10 years. At present the population in Kaliori District, Rembang Regency, when viewed from the population parameter, is included in the small town category, so the estimated population's water needs are around 80-120 liters/person/day according to the planning criteria of the Directorate General of Cipta Karya, Public Works [13]. Through this basic data, it is processed and obtained the value of domestic and non-domestic water needs for Kaliori District as in Table 1.

Table 1
Recapitulation of Domestic and Non-Domestic Water Needs in Kaliori District, Rembang Regency

No.	Allotment	Water Demand Year- (lt/s)				
		2022	2024	2027	2030	2032
1	House Connection (Domestic)	49.98	50.75	55.91	57.19	58.06
2	Public Hydrant (Domestic)	6.21	6.31	6.45	6.60	6.70
3	Non Domestic	6.50	6.53	6.55	6.57	6.59
Total (lt/s)		62.70	63.58	68.91	70.36	71.35

3.4 Discussion to Prevent Drought

Drought management in Indonesia requires cooperation between the government and the community. This is very important in overcoming the impact of drought ahead of the dry season. Preventive measures that can be taken for the drought that occurred in Kaliori District, Rembang Regency include interconnecting rivers, using rubber weirs in developing water resources, and optimizing existing ponds. River interconnection as one of the solutions to open, connect one stream to another in an effort to increase the water discharge of water availability in raw water.

Rubber weir is the result of the development of a fixed weir type into a motion bending by making a bending body from the developed rubber tube. Rubber bending functions to raise the water level by inflating the body of the weir and lowering the water level by deflating it [14]. The opening of the weir can be done automatically by deflating the rubber tube, while the expansion can only be done manually. Compared with fixed weirs and door motion weirs, rubber weirs have advantages as well as disadvantages [15].

Optimizing the existing reservoir, what is meant by optimization is the results achieved in accordance with the wishes, so optimization is the achievement of results as expected effectively and efficiently. According to the Big Indonesian Dictionary, optimization comes from the word optimal which means the best, the highest [16]. Many optimizations are also interpreted as a measure where all needs can be met from the activities carried out [17]. According to Kreiner *et al.,* optimization is a measure that causes the achievement of goals[18]. In general, optimization is the search for the best value available from several functions given in a context. In an effort to optimize water availability, one method that can be used is an optimization approach. Optimization is a way to make the value of a function so that some existing variables become the maximum or minimum by taking into account the existing constraints [19]. Every engineering application uses optimization technique to minimize the cost or to maximize the benefit to the user. However, there are many new optimization algorithms ready to be explored or enhanced by researchers in water resources [20].

4. Conclusions

Rembang Regency is included in the category of high potential for drought in Central Java province. One of the sub-districts in Rembang Regency that is experiencing drought, namely Kaliori District. In this sub-district, 83% of villages there experience drought. The majority experience it for a period of 4-5 months in 1 year. There is also seawater intrusion. Then to reduce the impact of drought, the local government is dropping water. The water demand for the next 10 years in Kaliori District is 71.35 liters/second. Based on the existing conditions in Kaliori District, the next steps in research is to implement drought preparation strategies including interconnecting of rivers, implementing rubber weirs, and optimizing existing ponds.

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References

[1] Rossi, Giuseppe, and Antonino Cancelliere. "Managing drought risk in water supply systems in Europe: a review." *International Journal of Water Resources Development* 29, no. 2 (2013): 272-289. https://doi.org/10.1080/07900627.2012.713848

[2] Pathak, Abhishek A., and B. M. Dodamani. "Trend analysis of groundwater levels and assessment of regional groundwater drought: Ghataprabha River Basin, India." *Natural Resources Research* 28 (2019): 631-643. https://doi.org/10.1007/s11053-018-9417-0

[3] Logar, Ivana, and Jeroen CJM van den Bergh. "Methods to assess costs of drought damages and policies for drought mitigation and adaptation: review and recommendations." *Water Resources Management* 27 (2013): 1707-1720. https://doi.org/10.1007/s11269-012-0119-9

[4] Sethu, Vasanthi, Peck Loo Kiew, Swee Pin Yeap, and Lian See Tan. "Time to Get Serious about Sustainable Water Management." *Progress in Energy and Environment* 14, no. 1 (2020): 13-15.

[5] A. H. Roest, G. Weitkamp, M. van den Brink, and F. Boogaard, "Mapping spatial opportunities for urban climate adaptation measures in public and private spaces using a GIS-based Decision Support Model," *Sustain. Cities Soc.*, vol. 96, no. May, p. 104651, 2023, https://doi.org/10.1016/j.scs.2023.104651

[6] Huda, Abiyani Choirul, Ibnu Pratikto, and Rudhi Pribadi. "Karakteristik Lahan terhadap Kerentanan Pesisir Pantai Kabupaten Rembang, Jawa Tengah." *Journal of Marine Research* 8, no. 3 (2019): 253-261. https://doi.org/10.14710/jmr.v8i3.25268

[7] Prayudi, Sinatrya Diko, and Hulaima Nur Qonita. "Identifikasi Masalah Kekeringan Air di Wilayah Desa Babaktulung, Kecamatan Sarang, Kabupaten Rembang Dengan Pendekatan Lapangan Hidrogeologi dan Permodelan Spasial." *Pertemuan Ilmiah Tahunan Ke-4 Perhimpunan Ahli Air Tanah Indonesia (PAAI)* (2019): 1-7.

[8] A. W. Adi *et al.*, "Indeks risiko bencana Indonesia tahun 2021," pp. 11–3, 2022.

[9] S. I. M. Sabri, N. Sazali, A. S. Jamaludin, W. S. W. Harun, K. Kadirgama, and D. Ramasamy, "Investigation on Water Quality for Farmed Aquatic Species by IoT Monitoring System," *J. Adv. Res. Appl. Sci. Eng. Technol.*, vol. 31, no. 3, pp. 317–327, 2023, https://doi.org/10.37934/araset.31.3.317327

[10] Purwanto, Waid Agus, Erni Suharini, and Wahyu Setyaningsih. "Kearifan Lokal Masyarakat Desa Segoromulyo Kecamatan Pamotan Kabupaten Rembang Dalam Menghadapi Bencana Kekeringan." *Edu Geography* 6, no. 2 (2018): 153-161.

[11] Zhao, Xiuling, Weiqi Zhou, and Lijian Han. "Human activities and urban air pollution in Chinese mega city: An insight of ozone weekend effect in Beijing." *Physics and Chemistry of the Earth* 110 (2019): 109-116. https://doi.org/10.1016/j.pce.2018.11.005

[12] Naufal, Muhammad, Margaretha Widyastuti, Ahmad Cahyadi, Fajri Ramadhan, Indra Agus Riyanto, Tjahyo Nugroho Adji, and Eko Haryono. "Temporal variations of baseflow contribution to epikarst spring discharge in Gunungsewu karst area, Indonesia." In *E3S Web of Conferences*, vol. 125, p. 01014. EDP Sciences, 2019. https://doi.org/10.1051/e3sconf/201912501014

[13] Adi, Henny Pratiwi, and Slamet Imam Wahyudi. "The Comparison of Institutional Model in Water Management Board-A Case Study of Management on Polder Drainage System in Semarang, Indonesia." *International Journal of Sustainable Construction Engineering and Technology* 11, no. 1 (2020): 312-322.

[14] Setiyono, B., S. I. Wahyudi, and H. P. Adi. "Analysis of Construction Implementation Time and Cost Scheduling by Adjusting Budget Changes Due to the Covid-19 Pandemic (Case Study on the Randugunting Dam Construction Project)." In *IOP Conference Series: Earth and Environmental Science*, vol. 955, no. 1, p. 012007. IOP Publishing, 2022. https://doi.org/10.1088/1755-1315/955/1/012007

[15] Roehman, Fatchur, Slamet Imam Wahyudi, and M. Faiqun Niam. "Analysis of Physical Model Rubber Weir Contain Water as Motion Weir for Flood and Rob Handling." *International Journal of Civil Engineering and Technology* 10, no. 4 (2019): 219-27.

[16] Çalişkan, Murat, Serkan Simsek, Sevil Atalay Vural, and Ömer Beşalti. "Comparison of etanercept, etomidate and erythropoietin and their combinations in experimentally-induced spinal cord injury." *Turkish Neurosurgery* 26, no. 6 (2016). https://doi.org/10.5137/1019-5149.JTN.14036-15.1

[17] S. H. M. Fauzi and N. M. Jamil, "Wastewater Treatment Process: A Modified Mathematical Model for Oxidation Ponds," *J. Adv. Res. Fluid Mech. Therm. Sci.*, vol. 86, no. 1, pp. 76–86, 2021, https://doi.org/10.37934/arfmts.86.1.7686

[18] Kreiner, Helmuth, Alexander Passer, and Holger Wallbaum. "A new systemic approach to improve the sustainability performance of office buildings in the early design stage." *Energy and Buildings* 109 (2015): 385-396. https://doi.org/10.1016/j.enbuild.2015.09.040

[19] R. S. Wahyudi, S. I. Wahyudi, and P. H. Subagya, "Water quality evaluation used to function feasibility case study on Babon river in Semarang, Central Java, Indonesia," *IOP Conf. Ser. Earth Environ. Sci.*, vol. 612, no. 1, 2020, https://doi.org/10.1088/1755-1315/612/1/012034

[20] Ahmad, Asmadi, Ahmed El-Shafie, Siti Fatin Mohd Razali, and Zawawi Samba Mohamad. "Reservoir optimization in water resources: a review." *Water Resources Management* 28 (2014): 3391-3405. https://doi.org/10.1007/s11269-014-0700-5