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Addition of Criteria for the Drought Level Vulnerability to the Reservoir Location Priority

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Abstract*: Blora regency is mostly a water critical region during dry seasons due to its porous soil characteristic. In order to overcome this condition, in 2006, Indonesian Ministry of Public Works and Housing, through Mettana Engineering Consultant, conducted a Study of Identification and Basic Design Development of Reservoirs in Blora Regency. It determined 28 future reservoir locations by considering their technical, economical and socio-environmental aspects. However, for the reservoirs to be the most effective, it is necessary to include regional drought vulnerability aspect into consideration to determine their location priority. The main purpose of this research, to conduct an analysis of meteorogical drought vulnerability in Blora regency region.In more detail the main goal is to determine reservoir location priority in Blora regency region by considering meteorogical drought vulnerability aspect. Drought Index was calculated using SPI (Standardized Precipitation Index) method using 2009-2018 monthly precipitation data obtained from 15 precipation stations. Mapping of drought vulnerable regions was done using GIS (Geographic Information System) technology using spatial interpolation approach. This research determined new priority, different from that determined by Mettana Engineering Consultant. Priority 1 formerly consisted of Suruhan, Kedungwungu, Bangsri, Sambong and Kalisari reservoirs while the new one consisted of Polaman 1, Polaman 2, Suruhan and Jurangjero reservoirs. Suruhan reservoir appeared in both versions. Kedungwungu, Bangsri, Sambong and Kalisari reservoirs moved to priority 2 in the new priority since they were located in low drought level regions while Polaman 1, Polaman 2 and Jurangjero reservoirs moved to priority 1 since they were located in moderately high to moderate drought level regions. It indicated that is necessary to include drought vulnerability aspect into consideration in determining reservoir location, along with technical, economical and socio-enviromental aspects. The government then may employ this aspect as an additional criteria in developing future reservoir construction program to be more effective that targets drought vulnerable regions

***Keywords* : drought index, priority, reservoir, spatial interpolation .**

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I. INTRODUCTION

Blora regency is mostly a water critical region, especially at the limestone mountains part of it, due to its porous soil characteristic. Rivers flow only in wet seasons, contrary to the dry seasons when they dry up. It causes annual drought that leads to sizeable loses with the population suffer from lack of water supplies and farmers experience crop failures.

In 2006, Indonesian Ministry of Public Works and Housing (PUPR) through Mettana Engineering Consultant tried to overcome this situation by conducting reservoir construction program through study of Identification and Basic Design Development of Reservoirs in Blora Regency Region. The consultant conducted a desk study of identification of reservoir potential locations across Blora regency area. A total of 28 potential locations were determined, from which the study selected the reservoir priority and developed their basic designs. The identified reservoirs were located in Lusi river basin, which was the main river that covers almost the entire Blora regency region. The reservoirs were expected to help reduce flood risks as well as overcome drought in the region.

The reservoir location priorities were determined by considering their technical, economical and socio-environmental aspects. They did not include drought vulnerability aspect that may result that the reservoir location priorities be less effective. Therefore, it is necessary to add this aspect in the study conducted by Mettana Engineering Consultant to ensure that they are most effective.

Based on the literature survey aforementioned, the problem of this study can be formulated as: The effect of additional drought vulnerability aspect to reservoir location priority determined by Mettana Engineering Consultant study.

The main purpose of this research, to conduct an analysis of meteorogical drought vulnerability in Blora regency region.

In more detail the main goal is to determine reservoir location priority in Blora regency region by considering meteorogical drought vulnerability aspect.

II. LITERATUR REVIEW

A. Prior Researches

In 2006, Mettana Engineering Consultant [1] conducted Study of Identifying and Developing Basic Design of Reservoirs in Lusi River Basin in Blora Regency and determined 28 reservoir potential locations. Assesment of priority was conducted on all 28 reservoirs based on technical, economical and socio-environmental aspects in order to determine the top 5 reservoir priorities which were, in order, Suruhan, Kedungwungu, Bangsri, Sambong, Kalisari reservoirs.

Harjanti [2] conducted a research on Suitability of Reservoir Location based on GIS based SPI Method in Bodri Kuto River Basin. The result showed that of a total of 23 reservoirs, 5 (22%) of the locations were highly suitable, 5 (22%) were suitable and 13 (56%) were less suitable according to meteorogical drought distribution data obtained.

B. Standardized Precipitation Index (SPI)

Drought is basically a common natural phenomenon during dry seasons related to regional hidrological cycle. Drought results from a prolonged deficiency of precipitation that causes subsided water reserves and stream flows [3].

It has become a complex problem in water resources management in securing water availability since it occurs in a prolonged period gradually but has broader impacts compared to flood.

Water resources management requires clear information on drought regarding its beginning, end and duration as well as its severity. It is necessary to predict when the drought should happen and to evaluate prior occurances of the drought. Hatmoko [4] stated that Drought Index is a useful means to detect, monitor, and evaluate drought. Standardized Precipitation Index (SPI) is a meteorogical drought Index accepted worldwide and has been extensively used to study drought in Indonesia.

Ardiputro [5] stated that SPI Drought Index Method as in (1) is calculated based on precipitation deviation from its normal condition determined in a long timescale (monthly, two-monthly, quarterly and so on).

The method to analyze drought index by using SPI is shown in the following Formula:

$$SPI = Z_{ij} = \frac{X_{ij} - \bar{X}_j}{\sigma_j} \quad (1)$$

where:

SPI = Standardized Precipitation Index
Z_{ij} = Variable Z, in year-i month-j.
X_{ij} = monthly precipitation in year-i month-j.
$\bar{X}_j$ = average precipitation in month-j.
σ_j = standard deviation in month-j.

While for calculation standart deviation (2) is shown :

$$\sigma = \sqrt{\frac{\sum_{i=1}^{n} (X_i - \bar{X})^2}{n-1}} \quad (2)$$

where:

X_i = precipitation for month-i
σ = standard deviation
$\bar{X}$ = average precipitation
n = number of data

Nine classes in SPI value classification system according to Consultative Group on International Agricultural Research (CGIAR) [6] is shown in Table 1.

Table I Nine Classes In SPI Value Classification System According to CGIAR

CGIAR SPI Values Classification	Classification
> 2,00	Extremely Wet
1,50 – 2,00	Very Wet
1,00 – 1.50	Wet
0,50 – 1,00	Moderately Wet
-0,50 – 0,50	Normal
-1,00 – -0,50	Moderately Dry
-1,50 – -1,00	Dry
-2,00 – -1,50	Very Dry
< -2,00	Extremely Dry

C. IDW (Inverse Distance Weighted)

Limited number of sample data available may create difficulties in processing data by using GIS (Geographic Information System).

The incomplete sample data may require several data interpolation methods in order to create the desired output. Data interpolation is a mathematical method to predict data values in points that the values are unavailable. Spatial interpolation is based on the assumption that data attributes are spatially continuous and correlated. Therefore data estimation can be made based on the data of the surrounding points and the point values that are close to one another are more alike than those that are farther apart [7]. IDW is an interpolation method available in GIS program. This interpolation method is necessay in analyzing limited number of sample data that require data prediction. IDW assumes that each input point has a local influence that diminishes with distance. Nearby data will have the most influence, and the surface will have more detail. The influence diminishes with distance and the surface will have less detail. Handareni [8] wrote in a research of IDW and Kriging Interpolation Methods regarding precipitation data and concluded that IDW interpolation method provided more accurate interpolation results than that of Kriging method as all results using IDW method provided values close to minimum and maximum values of the sample data while Kriging method provided narrower ranged values.

D. Reservoir

Irianto [9] stated that reservoir is a pond shaped water conservation structure used to contain run off and rain water as well as other water sources in order to support the population in their activities in farming, plantation and livestock. Reservoir is a structure that conserve excess water during high debit and release it when needed.

III. RESEARCH METHOD

precipitation for month-i

A. Location

Blora Regency is located at the eastmost part of Central Java Province directly adjacent to Rembang Regency and Pati Regency, Indonesia

B. Condition

This research was limited to the following conditions:

- Drought analysis was focused on meteorological aspect by using SPI (Standardized Precipitation Index) method and CGIAR scales (2012) based on precipitation data for the period of 2009 to 2018.
- Reservoir locations being analyzed were considered technically qualified.
- Objects of the study were 28 reservoir locations provided by desk study conducted by Mettana Engineering Consultant in 2006.
- Analysis was done on precipitation stations as control points at 15 different locations that provided complete precipitation data.
- Data interpolation was done by using IDW (Inverse DistanceWeighted) method.

C. The Data

This research requires data of:

- Precipitation data for a period of 10 years (2009-2018).
- Spatial data of 15 selected precipitation stations located in Blora Regency and the surrounding area.
- Spatial data of reservoir location priority provided by desk study conducted by Mettana Engineering Consultant in 2006.

D. Analytical Stages

Data processing was done in accordance with applicable procedures and theories to obtain the desired results based on the data available. The analytical stages done were as follow::

- Generation of unknown precipitation data
  Unknown precipitation data was generated by using Reciprocal method using precipitation data obtaines from nearby stations, by considering their distance as a determination factor.
- Precipitation data testing and correction.
  Data testing was done by using double mass curve to investigate data consistency, with inconsistent data then be adjusted.
- Calculation of Drought Index.
  Calculation of dought index values was done by using SPI method for every selected precipitation station. The indices were then added to spatial data attributes of selected precipitation station.
- Spatial Interpolation.
  Spatial interpolation was done for spatial data of pecipitation stations combined with the SPI drought index by using IDW method using ArchMap available in GIS program.
- Classification Drought Level.
  It was done by classifying drought level of interpolation results into 9 CGIAR scales, from > 2 (extreme wet) to < -2 (extreme dry)
- Mapping of monthly drought distribution .
  Drought level classification as a raster dataset was then exported to shapefile (.shp).
- Mapping of Drought Vulnerable Regions.
  It was a mapping of drought vulnerable regions at village/district level, with SPI values less than -1,00 to be classified ‘dry’ to ‘very dry’. Analysis was done for 2009-2018 period by calculating how many ‘dry’ to ‘very dry’ conditions reoccured in the region during the period.
- Additional of drought vulnerability criteria to consideration of reservoir location determination.
  It was done by reevaluating reservoir location priority based on PT. Mettana Engineering Consultant by adding drought vulnerability aspect based on drought vulnerable regions map into consideration.
- Discussion and Conclusion.
  Discussion was conducted by comparing priorities prior and after the additional of drought vulnerability criteria to determine their differences. It was intended that it can support water management authority in deciding on developing plan regarding drought and future reservoir construction priorities.

IV. RESULTS AND DISCUSSION

Intersect of monthly drought distribution in Blora Regency for 2009 to 2018 period showed the areas with dry months as many as 9 to 42 times. For the purpose of map simplification, these drought vulnerable area were classified into 6 classes, as shown in Table 2.

Table II Classification of Drought Vulnerability Level.

No.	Number of dry months	Vulnerability Level
1	36 – 42	Extremely High
2	29 - 35	High
3	24 - 28	Moderately High
4	19 - 23	Moderate
5	14 - 18	Moderately Low
6	9 - 13	Low

Assesment of 28 reservoir priorities provided by Mettana Engineering Consultant in Blora regency regarding technical, economical and socio-environmental aspects ranged between 3.4 to 4.9 points, divided into 4 priority scales as shown in Table 3. This assesment did not consider meteorogical drought vulnerability aspect so that the reservoir locations may not be at drought vulnerable areas that make them less effective.

Table III Priority Scales Of Mettana Engineering Consultant

No.	Reservoir	Value	Mettana’s Priority
1	Suruhan	4,90	1
2	Kedungwungu	4,81	1
3	Bangsri	4,57	1
4	Sambong	4,56	1
5	Kalisari	4,56	1
6	Kedungmulyo	4,44	2
7	Semanggi	4,33	2
8	Tlogowungu 2	4,30	2
9	Jurangjero	4,23	2
10	Karangjong	4,16	2
11	Bedingin	4,14	3
12	Polaman 2	4,14	3
13	Klopoduwur	4,10	3
14	Tlogowungu 1	4,10	3
15	Jomblang	4,04	3
16	Polaman 1	3,98	3
17	Wonosemi	3,95	3

18	Dringo	3,78	3
19	Dologan	3,77	4
20	Gembol	3,77	4
21	Nglengkir	3,66	4
22	Sumberejo	3,62	4
23	Tunjungan	3,62	4
24	Kembang	3,59	4
25	Nglangitan	3,56	4
26	Soko	3,54	4
27	Blimbing	3,52	4
28	Singonegoro	3,40	4

Drought vulnerability aspect was added by plotting of reservoir location points into the map of drought vulnerability regions as shown in Fig. 1. It was done by evaluating the intersect result of reservoir locations in the drought vulnerability map, which showed that those 28 reservoirs were located at areas with "dry" condition as many as 9 to 25 times during 2009 to 2018 period. Reassesment was then done based on drought vulnerability criteria that consists of 4 classes as shown in Table 4, with the result shown in Table 5.

Table IV Assessment Criteria Based On Drought Vulnerabiltiy Aspect

No.	Number of Dry Months	Values Class
1	24 - 28 kali	4
2	19 - 23 kali	3
3	14 - 18 kali	2
4	9 - 13 kali	1

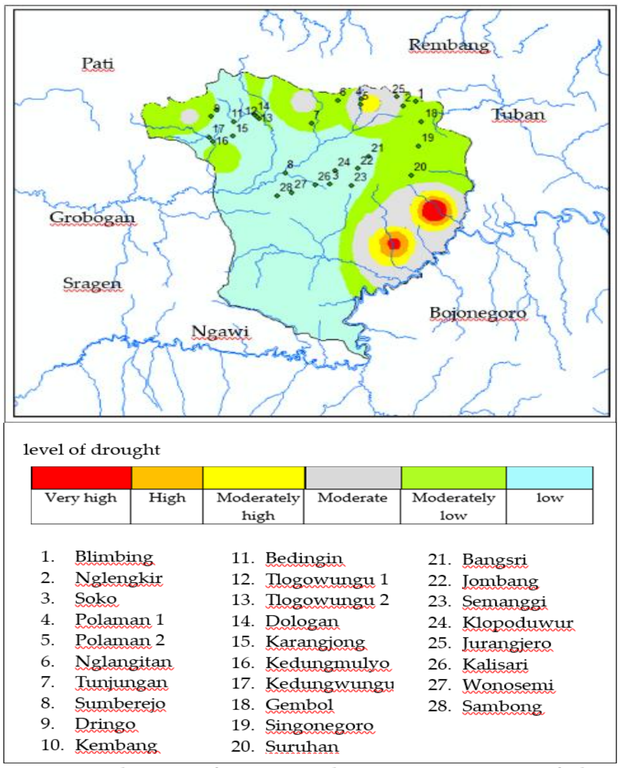

Fig. 1 Plotting of reservoir locations into map of drought vulnerability area

Table V Assessment Result Based On Drought Vulnerability Aspect

No.	Reservoir	Number of dry months	Value class
1	Polaman 1	25	4
2	Polaman 2	25	4
3	Jurangjero	19	3
4	Blimbing	15	2
5	Nglengkir	17	2
6	Nglangitan	18	2
7	Tunjungan	15	2
8	Dringo	14	2
9	Dologan	14	2
10	Gembol	16	2
11	Singonegoro	15	2
12	Suruhan	16	2
13	Sumberejo	11	1
14	Kembang	13	1
15	Bedingin	11	1
16	Tlogowungu 1	13	1
17	Tlogowungu 2	13	1
18	Karangjong	11	1
19	Kedungmulyo	12	1
20	Kedungwungu	11	1
21	Wonosemi	12	1
22	Sambong	11	1
23	Soko	10	1
24	Bangsri	10	1
25	Jombang	10	1
26	Semanggi	10	1
27	Klopoduwur	10	1
28	Kalisari	10	1

Combination between assessment conducted by Mettana Engineering Consultant and assesment based on drought vulnerability aspect with equal qualities and each of which divided into 4 classes was done by adding both values and is shown in Table 6.

The result of the combination were new class values as shown in Table 7

Based on the class values above, the order of priorities based on the assesment by Mettana Engineering Consultant was compared to the combination, with the highest class values are regarded as Priority 1 as shown in Table 8.

Table VI Assesment Based On Combination Between Mettana Engineering Consultant And Drought Vulnerability Assesments

No.	Reservoir	Class Values, Mettana	Class Values, Drough Vulnerability	Combination
1	Blimbing	1	2	3
2	Nglengkir	1	2	3
3	Soko	1	1	2
4	Polaman 1	2	4	6
5	Polaman 2	2	4	6
6	Nglangitan	1	2	3
7	Tunjungan	1	2	3
8	Sumberejo	1	1	2
9	Dringo	2	2	4
10	Kembang	1	1	2
11	Bedingin	2	1	3
12	Tlogowungu1	2	1	3
13	Tlogowungu2	3	1	4
14	Dologan	1	2	3
15	Karangjong	3	1	4
16	Kedungmulyo	3	1	4
17	Kedungwungu	4	1	5
18	Gembol	1	2	3
19	Singonegoro	1	2	3
20	Suruhan	4	2	6

21	Bangsri	4	1	5
22	Jomblang	2	1	3
23	Semanggi	3	1	4
24	Klopoduwur	2	1	3
25	Jurangjero	3	3	6
26	Kalisari	4	1	5
27	Wonosemi	2	1	3
28	Sambong	4	1	5

Table VII Assesment Based on The Combination, Sorted Based on Class Values

No.	Reservoir	Class Values Combination
1	Polaman 1	6
2	Polaman 2	6
3	Suruhan	6
4	Jurangjero	6
5	Kedungwungu	5
6	Bangsri	5
7	Kalisari	5
8	Sambong	5
9	Dringo	4
10	Tlogowungu 2	4
11	Karangjong	4
12	Kedungmulyo	4
13	Semanggi	4
14	Blimbing	3
15	Nglengkir	3
16	Nglangitan	3
17	Tunjungan	3
18	Bedingin	3
19	Tlogowungu 1	3
20	Dologan	3
21	Gembol	3
22	Singonegoro	3
23	Jomblang	3
24	Klopoduwur	3
25	Wonosemi	3
26	Soko	2
27	Sumberejo	2
28	Kembang	2

Table VIII Priorities Based on Mettana Engineering Consultant Assesment Compared to Assesment Based on the Combination

No.	Reservoir	Priority, Mettana	Reservoir	Priority, Combination
1	Suruhan	1	Polaman 1	1
2	Kedungwungu	1	Polaman 2	1
3	Bangsri	1	Suruhan	1
4	Sambong	1	Jurangjero	1
5	Kalisari	1	Kedungwungu	2
6	Kedungmulyo	2	Bangsri	2
7	Semanggi	2	Kalisari	2
8	Tlogowungu 2	2	Sambong	2
9	Jurangjero	2	Dringo	3
10	Karangjong	2	Tlogowungu 2	3
11	Bedingin	3	Karangjong	3
12	Polaman 2	3	Kedungmulyo	3
13	Klopoduwur	3	Semanggi	3
14	Tlogowungu 1	3	Blimbing	4
15	Jomblang	3	Nglengkir	4
16	Polaman 1	3	Nglangitan	4
17	Wonosemi	3	Tunjungan	4
18	Dringo	3	Bedingin	4
19	Dologan	4	Tlogowungu 1	4
20	Gembol	4	Dologan	4
21	Nglengkir	4	Gembol	4
22	Sumberejo	4	Singonegoro	4
23	Tunjungan	4	Jomblang	4
24	Kembang	4	Klopoduwur	4
25	Nglangitan	4	Wonosemi	4
26	Soko	4	Soko	5
27	Blimbing	4	Sumberejo	5
28	Singonegoro	4	Kembang	5

V. CONCLUSION

Based on the research it can be concluded :

1) This research determined new priority, different from that determined by Mettana Engineering Consultant. Priority 1 formerly consisted of Suruhan, Kedungwungu, Bangsri, Sambong and Kalisari reservoirs while the new one consisted of Polaman 1, Polaman 2, Suruhan and Jurangjero reservoirs. Suruhan reservoir appeared in both versions. Kedungwungu, Bangsri, Sambong and Kalisari reservoirs moved to priority 2 in the new priority since they were located in low drought level regions while Polaman 1, Polaman 2 and Jurangjero reservoirs moved to priority 1 since they were located in moderately high to moderate drought level regions
2) The research indicated that drought vulnerability level of the area should be considered as a factor in determining reservoir location priority so that the reservoirs be most effective as they were to be built in the regions which need them most. Furthermore, the meteorogical drought vulnerability map can be used in later applications as a criteria in developing effective reservoir construction program related to drought.
3) This research has the limitations of the precipitaton station in Blora Region as a control point of mapping vulnerability locations so that to get adequate quality and distribution of hidrological data , it is necessary to have a density of precipitaton station locations from the management institution

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