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LOW-IMPACT DEVELOPMENT OF WATERSHED MANAGEMENT: A SUSTAINABILITY REVIEW ON GARANG RIVER WATERSHED IN SEMARANG CITY, INDONESIA

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Abstract

Management of river watershed is an important point in providing freshwater availability. The high level of pollution along the river's watershed of Garang watershed prove that the management of river watershed in Semarang city is not optimal. This research aims to assess the sustainability level of the river and identify key contributing factors. Applying quantitative method, this study uses survey to draw data. Data analysis used descriptive statistical methods with Multi-Dimensional Scaling (MDS) techniques. The sustainability review in this study is assessed from the input, process, and output dimensions. The study shows that management status of the Garang river watershed in Semarang City has a sustainability index value of 42.94, which is included in the continuous interval between the index values of 25-49.99. It means that Garang river watershed management is categorized as less sustainable. The less sustainable category of Garang river watershed management is caused by the conflicting policies, regulations, institutions, and management and unclear, inconsistent, and disharmonious regulations on watershed management within the scope of city government. This result will be very important to plan the Low-Impact Development for river watershed.

Key words: Indonesia, Low Impact Development, Multi-Dimensional Scaling, sustainability management, watershed

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1. Introduction

Watershed management is a holistic planning process that expands the scope of government policies in managing natural resources and development activities and at the same time is an effective tool for implementing sustainable development (Perera, 2017). River watershed is defined as an ecosystem consisting of hydrological and biophysical units that become a base or platform for the continuity of life and socio-economic activities in a particular environment (Peterson et al., 2021). The structure and function of watersheds in the perspective of sustainability are currently experiencing significant setbacks, especially due to pressures of population growth, urbanization, unsustainable development and management (Hidayati et al., 2020). Population growth causes an increase in the need or demand for water, food, and energy that can be obtained from watershed ecosystems (Russell et al., 2017). As a result of watershed exploitation, the impacts are on fish populations, flora and fauna habitats, and watershed recreational values (Khan et al., 2021). Pambudi (2019) stated that in Indonesia there is an increase of 3 critical watersheds every year. Critical watersheds as occurred at the Ciliwung watershed has

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impacted broadly toward the broad surrounding areas of the river (Febrianti et al., 2015; Fitri, 2020). It can be concluded that watershed management is important and should not be ignored in implementing sustainable development. It is related to the broad impact of the existence of rivers and their watersheds.

Studies on river watershed has been done by many researchers. The wide arrays of the research may be classified into some topics. The first are as done by David et al. (2022) and Courtney et al. (2023) that focused on the studies finding that watersheds are vital components of the environment because watersheds are serving as containers for rivers and tributaries, influencing water drainage, storage, and surface runoff, and providing habitats for various living organisms. The second are those focused on the relation between the climate changes and catchment characteristics and streamflow within watersheds, affecting overall hydrological processes (Julian and Ward, 2014; Lv et al., 2019). The next topic that become the focus of researchers are related to the importance of river and watershed restoration, rehabilitation, and conservation due to anthropogenic pressures that degrade water quality globally (Assireu et al., 2022). Population growth can directly impact water quality in natural water bodies within watersheds, highlighting the interconnectedness between human activities and environmental health (Liyanage and Yamada, 2017).

The other themes that become the interest of researchers are watershed morphometry as researched by Faski and Purnama (2021) who find that the factors like area, shape, and density of river flows that can influence water storage, surface runoff, and sediment transport within watersheds. Odiji et al. (2021) find that morphometry can aid in understanding the landscape and prioritizing conservation efforts, especially in regions like Northern Nigeria. Integrated watershed management fund by Tang and Adesina (2022) as essential frameworks for sustainable groundwater resources and ecosystem services in regions like West Africa Integrated watershed management involves considering natural and human resources, social, political, economic, and institutional factors to achieve specific social objectives within drainage basins (Katusiime and Schütt, 2020).

This study specifically focuses in the Garang river watershed section which include the Kreo river and Garang river. Specific case in this study is the pollution in Kreo river and Garang river. Pollution of the Kreo River upstream is due to leachate seepage from the Jatibarang Landfill. Pollution of the Garang river downstream by the sludge content Regional Company of Drinking Water "Tirta Moedal" in Semarang City. Pollution that occurs in the Kreo river is caused by leachate containing Chromium (Cr) and Lead (Pb) with a distribution of Chromium (Cr) concentrations can be detected up to ± 300 m, while Lead (Pb) concentrations can be detected up to 200 m from leachate outlet points in the Kreo River. Once Jatibarang landfill as a pollution source point is not managed well, it is estimated that Chromium will pollute the surrounding soil within 10 years and Lead (Pb) in the next 50 years starting from 2015 (Purba and Kamil, 2015). In Garang River, pollution is caused by the disposal of regional company's sludge waste containing heavy metal Aluminum (Al) (Yulianti and Sunardi, 2010). The data above shows that it is very urgent to manage the Garang river watershed.

The complexity of problems because of Garang River watershed is administratively covering the cross-district watersheds, Semarang and Kendal Regency (Fatahilah, 2013) that has resulted in watershed management problems. The problems arose because no integrated policy on the management of the watershed, and water resources should be managed holistically, comprehensively, and integrated in order to pursue the balancing economic and social benefits with the integrity, health, and sustainability of the environment and watershed ecosystems (Khan et al., 2021). Based on the description above this study has the purpose to assess the sustainability level of the river and identify key contributing factors. Knowledge of the sustainability status of watershed management will be used as a basis for developing watershed management concepts based on the Low Impact Development (LID) approach. The conceptual model of watershed management with the LID approach is the *novelty* offered through by this study. The model itself is an abstraction from the real world, so the model can become a tool to implement an observation or research (Purnomo, 2012).

Low Impact Development (LID*)* refers to systems and practices that use or mimic natural processes to protect water quality and aquatic habitats (Shafique and Kim, 2015). The concrete description of the LID in the field is the development of green infrastructure, which is appropriate for application to watershed management practices. The LID focuses on conservation activities by using small-scale engineering applications to control hydrology through infiltration, filtration, storage, evaporation, and runoff containment (Jokar et al., 2021). The benefits of applying LID in this study are in addition to applying natural features or resources available by nature, LID is also relatively cheap to use, and can overcome pollution, according to the case studies highlighted in this study.

2. Material and methods

2.1. Study area

Research on watershed management highlights the phenomenon of pollution in the Kreo River and Garang River in the Garang River watershed of Semarang City. The picture of the Garang watershed can be seen in Fig. 1. Garang River watershed is located between 110° 15' 43' – 110° 30' 37' E and 6° 54' 49' - 7° 11' 51' S with a watershed area of 52,965,199 Ha (Ujianti et al., 2021). The flow of the Garang watershed comes from the Kreo river, Kripik river and upstream Garang river which merges with the lower Garang river (Fatahilah, 2013).

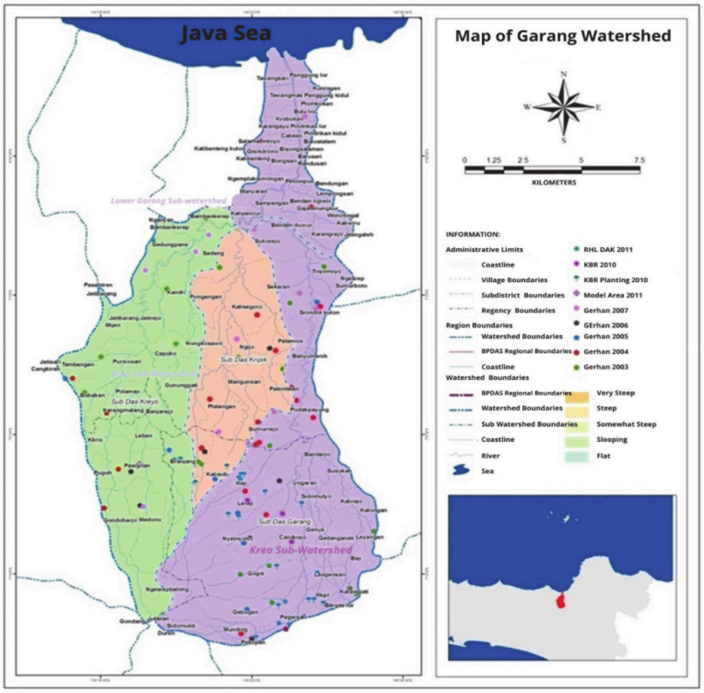

Fig. 1. Garang Watershed Map updated (Ujianti et al. 2021)

The reason the Garang River watershed was chosen is because even though this watershed crosses two administrative regions, namely Semarang Regency and Semarang City, this watershed is not well managed. Apart from that, the pollution that occurs in the watershed is caused by regional government-owned companies. These are several considerations that make important considerations in selecting the location for this research.

2.2. Research design

This research is an exploratory study. It meant that this research intended to conduct in-depth search, investigation, and analysis on the phenomena or problems that have not been clearly known or have never been recognized before with the aim of finding new solutions and/or opportunities that can overcome current problems (Mudjiyanto, 2018). Exploratory studies question questions that have never been questioned in previous research, and then explored and investigated in depth to find answers (Singh, 2021). The results of exploratory studies can be used as a basis for conducting further research aimed at building theories based on empirical experience or practice in the field. The follow-up research in question is qualitative research with strategies (Makri and Neely, 2021).

An exploratory study was used for diagnostic analysis on sustainability of Watershed Management in the city of Semarang. The output is in the form of Watershed Management sustainability status on a scale range of 0 – 100. This study has relevance to the importance of social and scientific domains. The purpose of this study is to describe the phenomenon of sustainability of watershed management and imply to the form of the design of Low-Impacted Development, which is the formula for making environmental recovery.

2.3. Data collection

This study uses some ways to get data: pre-research observation, document study, and survey.

Pre-research observation is doing observation and inspection before the research time (Coles et al., 2005). The activities in the terms of pre-research observation included the observation on the local of study, the availability of supporting data, as well as the feasibility to do the study. The research framework is prepared to achieve goals consisting of the formulation of research ideas through the stages of pre-research observation, so that problems that occur are identified to formulate problems from observations.

Quantitative data was collected through a survey on respondents using a questionnaire. The determination of the sample for the population is carried out using the Lemeshow formula (Levy and Lemeshow, 2013) which is applied directly to the results and discussion section.

2.4. Data analyses

Data was analyzed using descriptive statistical methods with Multi-Dimensional Scaling (MDS) techniques. Multi-Dimensional Scaling is a visual representation of distances or dissimilarities between sets of objects. "Objects" can be colors, faces, map coordinates, political persuasion, or any kind of real or conceptual stimuli (Kruskal and Wish, 1978). In this research, analyses of Multi-Dimensional Scaling (MDS) techniques will see the similarity of the problems that occur in the upstream and downstream areas of the Garang watershed. The phenomenon that emerges is river water pollution by pollutants.

The other tools of analyses used in this research are Rapid Appraisal of River Watershed Analyses. Reid and Dunne (1996) state that Rapid Appraisal of River Watershed Analyses is a tool of analyses which focus on the rapid assessment on watershed condition and sustainability indices such as *Rapid Appraisal of River Watershed Analysis*, *Leverage Attributes*, *Monte Carlo* values, Stress, and R^2.

The data combined in this study is the data that was used to analyze the sustainability of watershed management which consists of three dimensions; they are: (i) input dimension; (ii) process dimensions, and (iii) output dimensions with their respective attributes as described in Table 1.

The number of respondents who become sample are taken with sample calculations using the Lemeshow formula as follows (Eqs. 1-2):

$$p = 90\% = 0.9;\ (1 - p) = (1 - 0.9) = 0.1;\quad d = 10\% = 0.1;\ Z_{\alpha = 5\%} = 1.96 \tag{1}$$

$$n = \frac{1.96^2 .\ 0.9\,(1 - 0.9)}{0.1^2} = \frac{3.84.\,0.09}{0.01} = \frac{0.3456}{0.01} = 34.6 \tag{2}$$

Sample size (n) = 34.6 → rounded to 35 respondents.

The river watershed sustainability status analyses used Multi-Dimensional Scaling (MDS) technique with the Rapid Appraisal of River Watershed Analyses software tool. MDS is also called primary coordinate analysis (Abdi, 2013). The definition of MDS itself is a multiple-variable technique used to determine the position of an object based on an assessment of its similarity (Walundungo et al., 2014). The stages of the river watershed sustainability analysis process in Semarang can be illustrated in Fig. 3.

Table 1. Watershed management sustainability dimensions and attributes

Dimension	***Attribute***	***Concept***	***Scale***
Input	Policy	The set of concepts and principles on which plans and actions are based	**Multi Dimensional Scaling (MDS)**
	Authority	Related Institution Task	
	Strategy	Specific ways and techniques to achieve goals	
	Regulation	Regulate the use of norms or regulations	
	Institutional	All matters related to the institution	
	Operational concept	Design of operational activities	
	Budget	Estimated required costs	
	Infrastructure	Tools and equipment for carrying out activities	
Process	Planning	Creation of plans for the implementation of policies	
	Budget allocation	Allocation of available budget	
	Staff formation	Formation of executive staff	
	Organizing	Organizing the implementation of activities	
	Directing	Directing and moving activities	
	Control	Controlling the implementation of activities	
	Monitor and evaluate	Monitor and evaluate activities	
	Coordination	Coordinate activities	
	Accountability	Accountable	
Output	Efficiency	Output/input ratio	
	Effectiveness	Outcome/input ratio	
	Adequacy	Adequacy level of activity	
	Equitable	The degree of equitable distribution of activity results	
	Accuracy	The degree of accuracy of the results of activities	
	Justice (equity)	Fairness level of access and receipt of benefits	
	Responsiveness	Responsiveness to change	
	Vulnerability	Level of vulnerability to risk	

Source: Schraad-tischler and Seelkopf (2012)

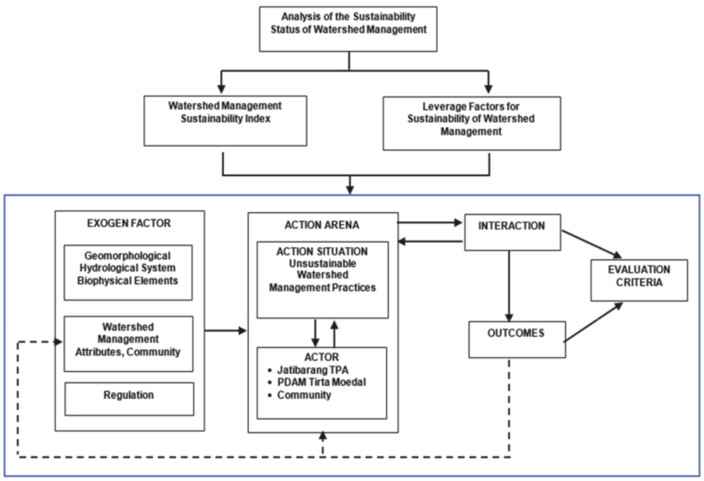

Fig. 3. Stages of watershed management sustainability analysis in Semarang city

The application of sustainability indices to watershed management performance is carried out by dividing these intervals into four interval classes as follows in Table 2.

Table 2. Watershed management sustainability index interval class

No.	*Sustainability Index*	*Category*	*Information*
1	0.00 – 24.99	Bad	Unsustainable
2	25.00 – 49.99	Less	Less Sustainable
3	50.00 – 74.99	Enough	Quite Sustainable
4	75.00 – 100	Good	Sustainable

With these four intervals, the level of sustainability quality of the river watershed management studied will be visible.

3. Result and discussions

3.1. Sustainability status of Garang River watershed

The sustainability status of Garang watershed management in the pollution study of the Kreo Rrver and Garang river of Semarang city was assessed from 3 (three) dimensions, namely input-process-output with the Rapid Appraisal of River Watershed tool. Rapid Appraisal of River Watershed uses all the principles of Rapfish (*Rapid Appraisal for Fish*) applied to measure the watershed sustainability index. In the results of data processing the Garang watershed management sustainability index, a diagram is produced as shown in Fig. 4.

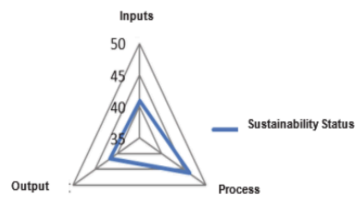

Fig. 4. Sustainability status diagram

Figure 4 shows that the measured sustainability index is in the category of less sustainability. The category of watershed management that is less sustainable is supported by the results of water quality checks of the Kreo River and Garang River as shown in Table 3 and Table 4. Data on Table 3 is obtained from the secondary data source (Regional Company of Drinking Water "Tirta Moedal" Semarang City). The data is based on analyses of water quality sample test carried out four times in a month. The results of the water quality inspection on the Garang river, which is the source of fresh water for Regional Company of Drinking Water "Tirta Moedal," show that it has decreased in quality. The decline in water quality is shown by several parameters exceeding the quality standards set by Government Regulation No. 22 of 2021 Class 1, which is intended as fresh material for drinking water. Parameters that exceed quality standards include colors that show an increase of 26 times higher than the maximum level allowed.

In addition to color parameters, there is an increase in the content of Iron (Fe), Ammoniac (NH_3), Copper (Cu), Sulfide (H_2S), Manganese (Mn), Selenium (Se), Phenol and the content of DO (*Dissolved Oxygen)* and BOD *(Biochemical Oxygen Demand).*

The same thing also happened to the water quality of the Kreo river, which showed increased levels in the color parameters, Iron (Fe), Ammoniac (NH_3), Sulfide (H_2S), Manganese (Mn), Biochemical Oxygen Demand (BOD) and *Chemical Oxygen Demand* (COD), as shown in Table 4.

The results of sustainability diagrams in data processing and Rapfish also gets results in the form of sustainability indices (*Rapid Appraisal of River Watershed Analysis*), *Leverage Attributes*, *Monte Carlo* values, Stress, and R^2 respectively described below.

Table 3. Garang River water quality

No.	Parameters	Unit	Maximum levels allowed	Examination Results			
				11/05/2022	17/05/2022	23/05/2022	25/05/2022
	I. Physics						
1	Temperature	°C	± 3	25.2	26.0	24.2	25.1
2	Color	Pt-Co	15	394*	108*	106*	382*
3	Turbidity	NTU	-	56.2	16.2	19.9	69.4
4	Electrical Conductivity	μΩ.cm	-	313	262	276	231
5	Solute Solids	mg/L	1000	156	131	138	116
	II. Chemistry						
1	pH	-	6.0 – 9.0	7.99	8.04	7.86	799
2	Organic Substances	mg/L	-	9.83	6.62	7.42	9.48
3	Hardness	mg/L	-	113.40	118.45	132.25	90.85
4	Calcium (Ca)	mg/L	-	67.20	71.04	78.72	54.72
5	Magnesium (Mg)	mg/L	-	46.20	47.41	53.53	36.13
6	Iron (Fe)	mg/L	0.3	0.67*	0.24	0.29	0.64*
7	Chloride (Cl)	mg/L	300	22.08	21.60	16.80	12.96
8	Ammonia (NH_3) as N	mg/L	0.1	0.77*	0.36*	0.45*	0.63*
9	Nitrite (NO_2) as N	mg/L	0.06	0.050	0.041	0.057	0.061*
10	Chromium (Cr)	mg/L	0.05	0.0	0.004	0.010	0.0
11	Zeng (Zn)	mg/L	0.05	0.01	0.0	0.0	0.01
12	Copper (Cu)	mg/L	0,02	0.08*	0.03*	0.0	0.01
13	Nitrate as N	mg/L	10	0.23	0.13	0.21	0.19
14	Fluoride (F)	mg/L	1	0.43	0.0	0.0	0.61
15	Cyanide (Cn)	mg/L	0.02	0.009	0.0	0.001	0.001
16	Sulfide (H_2S)	mg/L	0.002	0.054*	0.033*	0.022*	0.042*
17	Sulphate (SO_4)	mg/L	300	11	8	13	10
18	Manganese (Mn)	mg/L	0.1	0.173 *	0.112 *	0.088	0.135 *
19	Aluminum (Al)	mg/L	-	0.050	0.0	0.014	0.037
20	Cadmium (Cd)	mg/L	0.01	-	0.001	-	0.002
21	Selenium (Se)	mg/L	0.01	-	0.03 *	-	0.01
22	Detergent	mg/L	0.02	-	0.001	-	-
23	Phenol	mg/L	0.002	-	0.032 *	-	-
	III. Special						
1	Dissolved Oxygen (DO)	mg/L	6	7.9	9.1	5.1 *	6.0
2	Biochemical Oxygen Demand (BOD)	mg/L	2	3.1 *	2.0	1.9	1.4
3	Chemical Oxygen Demand (COD)	mg/L	10	5	7	3	4

Description: * Shows parameters that exceed the limit of regulation PP Number 22 of 2021 Class 1

Source: Regional Company of Drinking Water "Tirta Moedal" Semarang City

Table 4. Kreo River water quality

No.	Parameters	Unit	Maximum levels allowed	Examination results			
				05/01/2022	10/01/2022	01/17/2022	01/24/2022
	I. Physics						
1	Temperature	°C	± 3	27.1	25.3	26.1	27.6
2	Color	Pt-Co	15	76*	213*	87*	105*
3	Turbidity	NTU	-	28.6	105.0	34.90	60.70
4	Electrical Conductivity	μΩ.cm	-	216	196	182.7	184.5
5	Solute Solids	mg/L	1000	108	98	91	92
	II. Chemistry						

1	pH	-	6.0 – 9.0	8.04	8.02	8.10	8.14
2	Organic Substances	mg/L	-	16.43	13.46	12.96	15.64
3	Hardness	mg/L	-	88.2	69.30	64.05	66.15
4	Calcium (Ca)	mg/L	-	66	54	39	47
5	Magnesium (Mg)	mg/L	-	22.20	15.30	22.05	19.15
6	Iron (Fe)	mg/L	0.3	0.33*	1.04*	0.41*	0.54*
7	Chloride (Cl)	mg/L	300	15.18	13.34	10.58	11.04
8	Ammoniac (NH_3 as N	mg/L	0.1	2.38*	1.04*	0.41*	0.54*
9	Nitrite (NO_2 as N	mg/L	0.06	0.018	0.015	0.045	0.057
10	Chromium (Cr)	mg/L	0.05	0.005	0.010	0.020	0.002
11	Zeng (Zn)	mg/L	0.05	0.05	0.01	0.05	0.01
12	Copper (Cu)	mg/L	0.0	0.0	0.0	0.06*	0.02
13	Nitrate as N	mg/L	10	0.06	0.07	0.12	0.21
14	Fluoride (F)	mg/L	1	0.0	0.0	0.89	0.0
15	Cyanide (Cn)	mg/L	0.02	0.010	0.0001	0.004	00
16	Sulfide (H_2S)	mg/L	0.002	0.057*	0.141*	0.045*	0.044*
17	Sulphate (SO_4)	mg/L	300	7	7	7	11
18	Manganese (Mn)	mg/L	0.1	0.113*	0.235*	0.119*	0.118*
	III. Special						
1	Dissolved Oxygen (DO)	mg/L	6	6.4	6.2	6.7	7.5
2	Biochemical Oxygen Demand (BOD)	mg/L	2	3.6*	3.1*	2.0	2.2*
3	Chemical Oxygen Demand (COD)	mg/L	10	16*	7	22*	21*

Description: * Shows parameters that exceed the limit of regulation PP Number 22 of 2021 Class 1

Source: Regional Company of Drinking Water "Tirta Moedal" Semarang City

3.2. Input dimensions

The input dimension to determine the sustainability status of watershed management consists of policies, authorities, strategies, regulations, institutions, operational concepts, budgets, and watershed management infrastructure. Rapid Appraisal of River Watershed analysis on input dimensions obtained the following results in Table 5.

Table 5. Input dimension sustainability index

Dimension	***Index***	***Status***
Input	MDS: 40.91	Less Sustainable
	Monte Carlo: 40.99	
	Stress: 0.24%	
	R^2 : 0.86=86%	

Based on Table 5 it is confirmed that the MDS index is 40.91 in the sustainability class interval is between 25-49.99. Therefore, the sustainability of Garang River's watershed management in the Input dimension is categorized as less sustainable. As seen in Fig. 5, through the results of the Rapid Appraisal of River Watershed input dimension it is seen that the distribution of data exists at intervals of less than 50 and more than 20. In addition to the MDS index, a Monte Carlo value of 40.99 was also obtained, which explains the distribution of answers to respondents. If depicted in the form of a scatter plot, it appears in Fig. 5. The result data in Table 4 shows that the Input Index has a stress value of 0.24% and R^2 86. The stress value *(a lack of fit measure)* is the mismatch value from the calculation results. If the stress value is low or less than 0.25, then the calculation results show high accuracy, while R^2 is the square of the correlation coefficient as the *goodness of fit measure,* which shows the attributes on the dimension can explain the model. Rapid Appraisal of River Watershed analysis shows that the R^2 value is 86% so that the resulting data can be explained well by the model, and 0.24% stress value or mismatch measures are low so that it shows high accuracy.

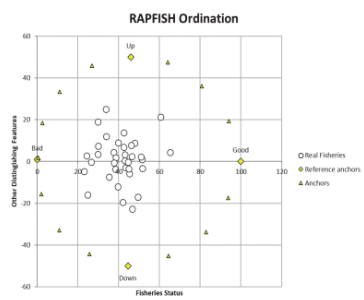

Fig. 5. Input dimension rapid appraisal of river watershed analysis

The results of calculating stress and R^2 values in the RapDAS tool are based on the sustainability dimensions analyzed using MDS. If the stress value is <0.24 and R2 is 86%. The R-squared value (R^2) is used to assess how much influence a particular independent latent variable has on the dependent latent variable. There are three grouping categories in the R square value, namely the strong category, moderate category and weak category (Hair et al., 2011). Hair et al stated that an R square value of 0.75 is in the strong category, an R square value of 0.50 is in the moderate category and an R square value of 0.25 is in the weak category (Hair et al., 2011). So, based on the R^2 value, it shows that the sustainability dimensions analyzed have a strong influence and can be used as a basis for preparing a sustainability formula model.

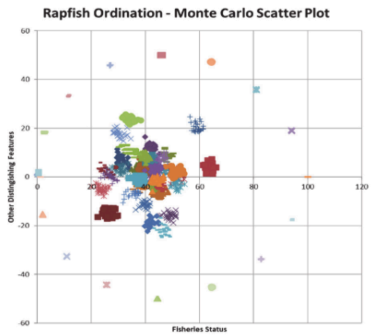

Fig. 6. Scatter plot Monte Carlo input dimensions

In addition to the above index, the results of sensitivity analysis or *Leverage Attributes* obtained to determine which attributes affect the sustainability status of management, as shown in Fig. 7. Based on the *Leverage Attribute* analysis in Fig. 7, one of the eight attributes most sensitive to affect the sustainability index of the input dimension is institutional because they have the highest value. In addition to institutions, policy as a middle value also affects the sustainability index. In watershed management practices, institutional components may become a determining factor for sustainability or not management. Thus, these attributes need attention to become the main focus in the implementation of watershed management. By improving institutional components, it can improve watershed management performance and increase the value of the watershed management sustainability index input dimension.

3.3. Process dimensions

The process dimension in determining the sustainability status of Garang river's watershed management in Semarang City consists of planning, budget allocation, staff formation, organizing, *directing*, control, monitoring and evaluation, coordination, and accountability. The results of the Rapid Appraisal of River Watershed analysis on the process dimension are given in Table 6.

Table 6 stated that the MDS index is 40.91 which is in the sustainability class interval between 25-49.99 so that the sustainability of Garang river's watershed management in the process dimension is categorized as less sustainable. In addition, the table also shows that the stress value is 0.22% and R^2 is 84. A low stress value (a lack of fit measure) indicates high accuracy, while R^2 (goodness of fit measure) indicates that the value of R^2 is 84%, so it can be said that the model can well explain the resulting data.

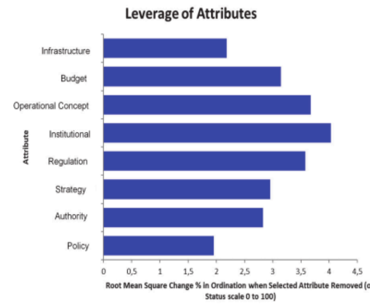

Fig. 7. *Leverage Attribute* input dimension

Table 6. Process dimension sustainability index

Dimension	*Index*	*Status*
Process	MDS: 46.26	Less Sustainable
	Monte Carlo: 46.56	
	Stress: 0.22%	
	R^2 : 0.84= 84%	

The MDS Index and Monte Carlo scatter plot can be seen in Fig. 8 and Fig. 9, respectively. In addition to the above index, the results of the *Leverage Attributes* analysis were obtained to determine the attributes that affect the sustainability status of Garang river's watershed management process dimensions, as presented in Fig. 10.

Based on the *Leverage Attribute* analysis in Fig. 10, one of the nine attributes that most sensitively affect the sustainability index of the process dimension is directing attributes or directing and driving activities. Thus, these attributes must be the main focus in implementing the Garang river watershed in Semarang city. So that the stages of the management implementation process can be directed and in accordance with the work plan or management program that has been made so that it can later increase the sustainability value of the Garang river watershed process dimension in Semarang city.

3.4. Output dimensions

The attributes of the output dimension in determining the sustainability status of Garang River's watershed management in Semarang City consist of efficiency, effectiveness, adequacy, equity, accuracy, fairness, responsiveness, and vulnerability. The results of the Rapid Appraisal of River Watershed analysis on the output dimension are shown in Table 7. Based on Table 7 it is stated that the MDS index is 41.66, which is in the sustainability class interval of 25-49.99, so the sustainability of Garang River's watershed management in the output dimension is classified as less sustainable. Table 7 also shows that the output dimension index has a stress value of 0.24% and R^2 is 85%.

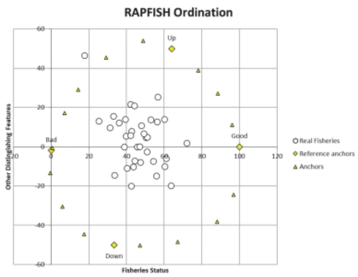

Fig. 8. Process dimension rapid appraisal of river watershed analysis

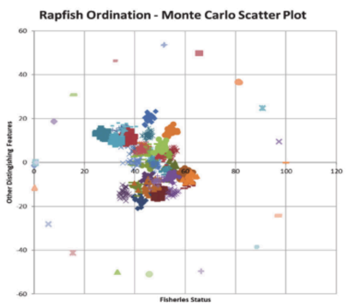

Fig. 9. Scatter plot Monte Carlo dimensional process

A low-stress value (a lack of fit measure) indicates high accuracy, while the value of R^2 (goodness of fit measure) shows a result of 85%, so it can be said that the data produced can be explained well by the model by 85% and the model cannot explain the rest.

The MDS index and Monte Carlo scatter plot on the output dimensions can be seen in Fig. 11 and Fig. 12, respectively. *Analysis of Leverage Attributes* to determine the attributes that affect the sustainability status of watershed management output dimensions is available in the form of Fig. 13. Based on the *Leverage Attribute* analysis in Fig. 13, one of the eight attributes that most sensitively affect the sustainability index of the output dimension is the accuracy attribute. In this case, the results of watershed management are intended to be appropriate in accordance with the characteristics of watershed problems.

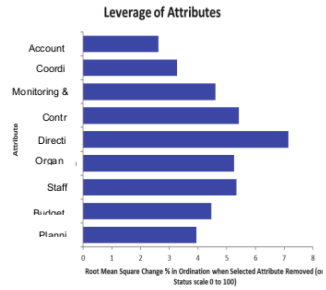

Fig. 10. Leverage of attributes process dimension

Table 7. Output dimension sustainability index

Dimension	***Index***	***Status***
Output	MDS: 41.66	Less Sustainable
	Monte Carlo: 41.82	
	Stress: 0.24%	
	R^2 : 0.85= 85%	

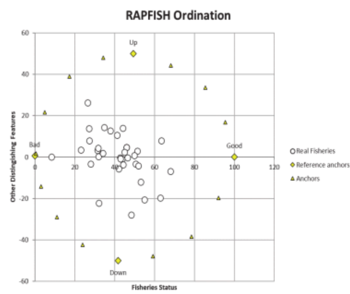

Fig. 11. Rapid appraisal of river watershed analysis of output dimensions

Thus, these attributes must be of more concern in realizing a sustainable of Garang River's watershed management in Semarang City. The status of Garang river Watershed Management in Semarang City received a sustainability index value of 42.94, which is included in the continuous interval between the index values of 25-49.99, so that it is categorized that the management of the Garang river Watershed is less sustainable. Leachate water pollution of the Jatibarang landfill in the Kreo river and sewage sludge pollution of Regional Company of Drinking Water "Tirta Moedal" in the Garang river have been going on for more than 10 years and are still happening today.

Leachate water pollutants cause river water quality to drop, above the permissible value according to PP Number 22 of 2021 concerning Class 1 Designation of drinking fresh water. The sludge pollutants produced by regional company cause an increase in color, Iron (Fe), Ammoniac (NH_3), Copper (Cu), Sulfide (H_2S), Manganese (Mn), Selenium (Se), Phenol and DO (Dissolved Oxygen) and BOD *(*Biochemical Oxygen Demand*)* content above the quality standard value as well as anthropogenic factors, namely the entry of household waste.

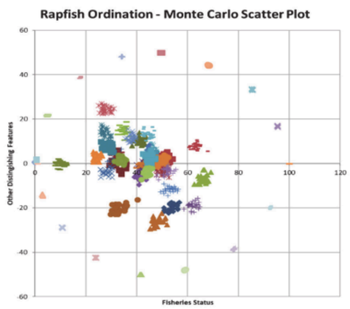

Fig. 12. Scatter plot Monte Carlo output dimensions

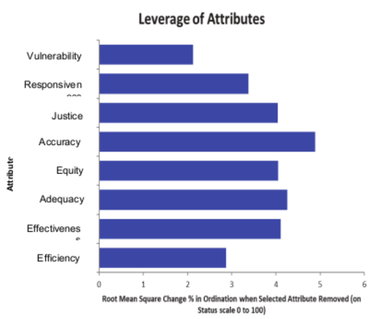

Fig. 13. Leverage attribute output dimension

3.5. Key factors contributing the low sustainability level of Kreo and Garang River

3.5.1. Technical problems

Kreo river water upstream and Garang river water downstream is the fresh materials for regional company's drinking water production. Leachate water pollution occurs due to waste processing with *open dumping* techniques at the Jatibarang landfill, while the practice of discharging sewage sludge directly into the Garang river water body occurs because the regional company does not have a *wastewater treatment plant* (WWTP) until it is still in the process of being made. Kreo river and Garang river are within the topographical and geographical scope of the Garang watershed in Semarang City. Still, these pollution practices have not been able to arouse concern to highlight them from the point of view of watershed management. An issue arises in the city of Semarang about using water as a resource. Issues about watersheds and their management never occur at the micro-scale of districts/cities but only resonate at the meso scale (Province) or macro scale (National/Central Government).

3.5.2. The problematic situations in the management of the Garang watershed in Semarang city

(i) Watershed management practices are not yet sustainable;

Based on the results of the analysis of INPUT dimension values compared with real conditions in the field, it shows that the problems in watershed management in Semarang city are policies and regulations.

(ii) Policy, regulatory, institutional, and management conflicts;

Watershed management has disappeared from the arena of action at the district/city level since the enactment of Local Government Law No. 23/2014, which negates the authority of district/city governments to manage watersheds. This situation is problematic for the Semarang city government because it is the ruler of an autonomous region and, at the same time, a user of watershed ecosystem services but does not have the responsibility, authority, and role to manage the watershed.

(iii) Unclear, inconsistent, and disharmonious regulations.

This condition can be seen in the context that if a problem occurs in the watershed area, the relevant institutions will shift responsibility to each other. Their reason for abdicating responsibility is state regulations. This is because the existing rules are not in line with each other.

3.5.3. Constraints in Garang river's watershed management

To form a sustainable watershed management model, it is necessary to pay attention to the constraints of the Garang watershed. The constraint factors mentioned as explained above are supported by the results of multivariate analysis which show that the constraint components have a strong value or influence (attributes of leverage).

Firstly, watershed conflicts, which are interpreted as impacts arising from the loss of watershed management authority at the District/City level in accordance with the annex to the regulation of Law Number 23 of 2014 concerning Regional Government, resulting in organizing problems in watershed management.

Second, the implications of watershed conflicts cause differences in interests, goals, and priorities in managing watersheds. It can happen because no organization is an organizational umbrella between watershed management stakeholders.

Thirdly, the unclear organizational umbrella and differences in interests, goals, and priorities in carrying out watershed management causes weak concepts and practices of collaboration between watershed management stakeholders.

Fourthly, the weak concept and practice of collaboration impact weak collective action in management. Due to overlapping regulations, watershed management is less efficient and effective.

Fifth, the number of watershed management bodies with unclear regulatory situations results from weak coherence, integration, and management coordination.

Sixth, although many institutions or organizations manage the Garang watershed, if there are problems related to watersheds that impact costs or *costs,* they tend to throw responsibility on each other because of budget constraints in each agency.

Seventh, the lack of application of STI (Science, Technology, and Innovation) in managing watersheds by utilizing existing natural resources has become less developed Garang watershed management in Semarang City.

Based on the description above, it can be seen that watershed management constraints are based on the absence of *i*ntegration tools of watershed management cooperation, persons or organizations that integrate watershed management activities, and overlapping authority due to regulatory gaps related to watershed management. In the Rapid Appraisal of River Watershed analysis, it has also been mentioned that the components or attributes of leverage that can have a strong influence in the implementation of watershed management include institutional, *directing* (direction and movement of management practices), and accuracy in the implementation of watershed management, stakeholders need to pay attention to these components in implementing watershed management.

Data that is exposed in this study may be oriented toward the watershed management design of LID which is defined as an innovative approach in soil development engineering that manages stormwater runoff at the site of a fall to restore the natural hydrological cycle and water quality. The basic philosophy of the LID is to design a nature-based regional landscape (watershed, urban or public space). The main goal is to obtain a natural hydrological profile by designing the landscape layout in such a way that hydrological functions can run in balance (Fletcher et al., 2015). LID is a green approach to manage rainwater by mimicking the natural hydrological system. In addition, the LID aims to slow, cleanse, absorb, and capture urban runoff and precipitation, thereby reducing water pollution, replenishing local aquifers, and increasing water reuse (Shafique and Kim, 2015). The LID approach is implemented through the application of green infrastructure which is a combination of natural engineering and structural engineering (Zimmer et al., 2012).

4. Conclusions

The Garang river watershed which includes two rivers, namely the Garang river and the Kreo river, has a low sustainability value. This low level of sustainability value is very worrying because these two rivers are the source for the Regional Company of Drinking Water "Tirta Moedal" to produce drinking water for the needs of the residents of the city of Semarang and its surroundings.

The high level of pollution with the content of mineral elements that are not beneficial for health does not receive enough attention, even though the Garang river watershed is in two administrative regions. Weak cordination between institutions and regions followed by weak knowledge regarding the importance of watershed cleanliness for human life is the cause of this condition.

The limitation of this study is that this incident only focuses on the Garang river watershed study area. With the focus of the study on the level of sustainability and the factors that cause the low level of sustainability in the Garang river watershed, of course this study is actually still very limited. There are many variations in natural and structural conditions that can be studied further.

Therefore, there are still opportunities for other researchers to conduct similar studies on different watersheds with different themes, problems and approaches. The diversity of studies will enable the discovery of watershed development models that are healthier, more profitable and sustainable.

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