

Developed watershed classification index determining management priority level based on watershed carrying capacity

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Abstract. Watershed classification index is important in terms of determining watershed management priority level based on its carrying capacity score whereby currently watershed is classified into two indexes which are “to be maintained” if the carrying capacity score is below 100 and “to be restored” if it is above 100. This index fails to capture existing condition where there are watersheds with carrying capacity score in between 90 and 110. The purpose of this paper is to propose developed watershed classification index to determine management priority level based on watershed carrying capacity score. The method used to develop the watershed classification index is Classification Interval approach. The analysis is resulting in rigorous management priority level based on developed watershed classification index which is $50 < \text{carrying capacity} \leq 90$ as Priority 3 (watershed indexed as “to be maintained”), $90 < \text{carrying capacity} \leq 110$ as Priority 2 (watershed indexed as “to be improved”) and $110 < \text{carrying capacity} \leq 150$ as Priority 1 (watershed indexed as “to be restored”). Therefore, the correct management priority level for Gangsa Watershed that has carrying capacity of 106 is Priority 2.

1 Introduction

Watershed management is a human action aimed to make sure that the usage of the Watershed resources is through the integrated ecosystem approach to maintain those resources by doing a balance conservation of water quantity, land, vegetation, and other natural resources [1], thus decreasing or avoiding the negative impact at the downstream [2]. Considering the fact that Watershed management action needs big fund [3] and involves multi stakeholders, hence urgency level is needed [4]. Watershed management urgency level (Priority Scale) is an important element in watershed management, so that the activity plan that is chosen scientifically can be made right on target in order to be effective, suitable, and sustainable. To determine the category of a Watershed condition whether it is healthy or not, is by doing the support capability assesment [5].

A healthy Watershed is the one which has ability to supply the needs of all ecosystem [6] that is used as an assesment of how good resources management activity balancing the anthropogenic need, ecology function and integrity in watershed [7]. To determine the watershed health condition, it is necessary to be evaluating and monitoring. Watershed management is important because it can

monitor whether the activity is done from time to time and has been progressing to or away from the target [7].

Furthermore, that activity is to asses whether there are changes in the watershed compared to the previous condition, whether those changes meet the set target and standard, and also whether it can be called successful, it needs to be reported to help the sustainable implementation decision guide [8].

The watershed priority scale determination becomes important in terms of watershed management [9] and it is used as management program plan, necessary in developing management identification, developing maintenance plan, and can help taking prevention acts needed in an a priori condition [10], including problems of limited funding [11]. Given the fact that in Watershed management, big investation fund is needed [12], thus a scientific analysis is needed [3]. The current condition in Indonesia is when the watershed classification index based on the support capability is released, where the total score of watershed classification index (<100), watershed support capability is maintained, if (>100), watershed support capability is recovered, thus those results are hoped to project the urgency level of watershed management reviewed [13,14,15], this thing is the

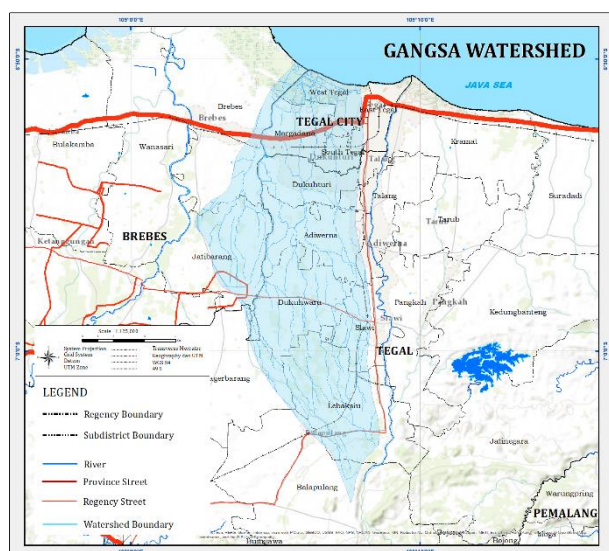
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problem, where the classification does not scientifically match the class interval score of watershed support capability and its category, hence, need a further review. The purpose of this paper is to determine the watershed classification index as a development to get an image of the watershed management urgency level (priority scale) according to its support capability score.

2 Material and methodical approach

2.1 Research location

Gangsa watershed region is located in between 109°02'17"-109°08'04" East Longitude and 06°48'58"-07°04'11" South Latitude. According to government administered territory, GANGSA watershed is counted as



Tegal Regency and Tegal City's territory. GANGSA watershed length is about 30 km with vastness of 93.62 Km².

Fig. 1. Map of Gangsa watershed

Gangsa watershed is one of watershed development (SWP DAS) in Pemali-Comal, where it was ranked on the 9th and 10th out of 11 Prioritized Watershed areas that needed to be thoroughly handled intergratedly in immediate time.

Geological condition of Gangsa watershed is divided into 2: Alluvium and Alluvium Facies. The Alluvium spans 13.442,17 ha across the Brebes District, whereas the Alluvium Facies spans for 6.498,60 ha. The Alluvium plain has a flat topography, which was formed through the process of alluvium deposition at the right and left side of the river.

The monitoring and evaluation impelementation of watershed development have a major necessity and play a big factor in water system protection, supporting the continuity in improving agriculture produtivity, and also as the vital security and protection for residences. At the midle of Gangsa watershed until the downstream, there are urban cities with high citizen density whose existence depends on the upper region: water supply compliance,

flood control, environment preservation, and human wisdom in exploiting the available natural resources.

2.2 Substance and material

This research uses various supporting tools such as Global Positioning System (GPS) to determine and pinpoint the observation location, ArcGIS application to process the spatial data, digital camera to record the field data, and computer to process and analyze data, also as a research instrument as primary data base.

Substances used in the research consist of Landsat imaging and digital spatial maps such as: Land Coverage map and Land Exploitation map. The map for watershed, river, earth structure, topography, administration, land capabilities, hydrology data covers rainfall volume and sedimentation.

2.3 Analytical technique

The analytical technique for processing data is done through several stages.

- First stage is to collect and select data, to choose tabulation data, primary or seconday data used within this research.
- Second stage is deducing the class classification according to its support capabilities through class interval approach analyzed with MS Excel program.
- With two stages done, the process moves on to determine the class classification for watershed support capability scale and its priority scale.
- Next is applying the watershed capability scale and prioritizing scale on Gangsa watershed. The watershed support capability assessment is analyzed with the assistance of Excel program, covering 5 (five) criteria which are: land condition, water system, socio-economic, building investment, and space utilization.
- After Gangsa watershed support capability value is gained, it is later compared between the old priority and support capability with the new one according to the class interval.

3 Results and discussion

3.1 Class interval value and watershed support capability categorization

The value criteria to determine the watershed classification according to its support capability in Indonesia covers 5 criteria and 15 sub-criteria [13,14] e.g. the land condition (40%), water system (20%), socio-economic (20%), building investment (10%) and space utilization (10%), with total value ranging from 50 to 150 (see table 1).

Table 1. Watershed support capability assessment parameter

Num	Criteria / Sub-criteria	Quality		Value	
		Score	%	Lowest	Highest
1	Land	40	20	20	60
	1.1 Critical land / li putan veg woods			10	30
	1.2 Land exploitation suitability			5	15

Num	Criteria / Sub-criteria	Quality		Value	
		Score	%	Lowest	Highest
2	1.3 Erosion Index (EI) / Factor Value CP	10		5	15
	Water System			10	30
	2.1 FlowRegime Coefficiency	5		2.5	7.5
	2.2 Annual Flow Coefficiency	5		2.5	7.5
	2.3 Sedimentary Content	4		2	6
	2.4 Flood	2		1	3
2.5 Water Use Index	4		2	6	
3	Socio-economic and Institutions			10	30
	3.1 Residents' Land Density	10		5	15
	3.2 Residents' Welfare	7		3.5	10.5
	3.3 Norm Existence and Enforcement	3		1.5	4.5
4	Waterworks Investment Value			5	15
	4.1 Cities Existence	5		2.5	7.5
	4.2 Waterworks Investment Value	5		2.5	7.5
5	Space Utilization			5	15
	5.1 Protected Area	7		2.5	7.5
	5.2 Distinguished Area	3		2.5	7.5
	Total			50	150

Watershed support capacity assessment in each class or class total, for every criteria and sub-criteria, consists of 5 scoring categories from very good, good, fair, poor, to very poor. The range value (R) is 100, counted from the highest (150) minus the lowest (50). The length or class interval score is 20, resulted from the division of 100 as range value (R) and 5 as the category value. From the mentioned calculation, the Class Interval Score and Watershed Support Capability are gained (see table 2).

Table 2. Class interval score and watershed support capability

Score (Class Interval)	Category
50 ≤ "Watershed Support Capability" ≤ 70	Very Good
70 < "Watershed Support Capability" ≤ 90	Good
90 < "Watershed Support Capability" ≤ 110	Fair
110 < "Watershed Support Capability" ≤ 130	Poor
130 < "Watershed Support Capability" ≤ 150	Very Poor

3.2 Watershed classification criteria toward watershed support capability value

In accordance to Indonesia Governmental policy, *Permenthut* number 60 in 2014 established the criteria of watershed classification, with the purpose of being used as the guidelines or reference for the related institutions in managing the watershed development in order whether to maintain or to recover the watershed support capability. Basing on the Interval scores and the watershed support capability for future development, it is needed to classify these data into 3 categories: one prioritized to maintain its support capability (Very Good and Good), one needed to be improved (Fair), and one that needed its support capability to be recovered (Poor and Very Poor), as can be seen in table 3 below.

Table 3. Watershed classification to its support capability

Score (Class Interval)	Category	Watershed Classification
50 ≤ "Watershed Support Capability" ≤ 70	Very Good	Maintained
>70 "Watershed Support Capability" ≤ 90	Good	
>90 "Watershed Support Capability" ≤ 110	Fair	Improved

>110 "Watershed Support Capability" ≤ 130	Poor	Recovered
>130 "Watershed Support Capability" ≤ 150	Very Poor	

From table 3, it can be seen that the watershed classification of "Improved" is the threshold or the unstable (critical) class, in which if the value decreases even for a bit then that class will face a change to its worse condition, and if the value increases then the condition changes into a better one.

3.3 Prioritized scale determination in watershed management

According to governmental policy *Permenthut* number 60 in 2014, the result of watershed classification criteria does not meant to be used as the basis for determining which forest and land rehabilitation technique, nor the water resource development technique to use. Yet it is expected to give an illustration of how dire the urgency in managing the watershed in national, province, and even regency/city area scale. The Indonesia government, in watershed management issue, has established 2 (two) Watershed Classification toward its support capability, if the value (Watershed Support Capability <100) then that watershed is maintained and if the value (Watershed Support Capability >100) then that watershed needs its support capability to be recovered. These assessments do not vividly show the urgency level in neither managing the watershed nor referring to the class interval score and the category. Presented below is the watershed classification according to the current watershed support capability (Table 4).

Table 4. Watershed classification according to its support capability

Value	Watershed Classification
"Watershed Support Capability" ≤ 100	Maintained
"Watershed Support Capability" > 100	Recovered

Whereas the priority scale determination in accordance to the current support capability situation can be seen at Table 5, in which the interval score does not refer to the class interval.

Table 5. Watershed priority category according to its support capability

Value	Category
100 < "Watershed Support Capability" ≤ 200	Priority III
200 < "Watershed Support Capability" ≤ 300	Priority II
300 < "Watershed Support Capability"	Priority I

Since the urgency level (priority scale) is important in the establishment of watershed management, so it is needed to have the criteria to set the urgency level (prioritized scale) that will be used as the basis of determining the next concrete steps to be done according to established urgency level. As an effort of development,

I present 2 (two) urgency level (prioritized scale) of watershed cultivation management. Scheme A (first) is divided into 3 (three) urgency levels which are the priority scale III (Maintained support capability watershed), priority scale II (Improved support capability watershed), and priority scale I (Recovered support capability watershed).

Table 6. Prioritized scale scheme A (first) table

Score (Class Interval)	Urgency Level
50 < "Watershed Support Capability" ≤ 90	Priority-III
90 < "Watershed Support Capability" ≤ 110	Priority-II
110 < "Watershed Support Capability" ≤ 150	Priority-I

Scheme B (second) is divided into 5 (five) urgency levels, the priority scale V and IV (Maintained support capability watershed), priority scale III (Improved support capability watershed), and priority scale II and I (Recovered support capability watershed).

Table 7. Priority scale scheme B (second)

Score (Class Interval)	Urgency Level
50 ≤ "Watershed Support Capability" ≤ 70	Priority-V
70 < "Watershed Support Capability" ≤ 90	Priority-IV
90 < "Watershed Support Capability" ≤ 110	Priority-III
110 < "Watershed Support Capability" ≤ 130	Priority-II
130 < "Watershed Support Capability" ≤ 150	Priority-I

3.4 The priority scale application on gangsa watershed

The criteria used to determine the Gangsa watershed [13,14] support capability is done intergratedly in 5 (five) criteria and 15 (fifteen) sub-criterias. It consists of the land condition (critical percentage, vegetation coverage percentage, erosion index, water system coefficient (Flow Regime Coefficiency (FRC)), Annual Flow Coefficient (AFC), Sedimentary Content, Flood, Water Use Index (WUI), Socio-economic Criteria (Residents' Land Density, Residents' Welfare, Norm Existence and Enforcement), Building investment criteria (City classification, Building value), and Space utilization criteria (Protected and Cultural Area). According to Gangsa watershed support capability for each criteria and assessment criteria [13,14].

Table 8 Class criteria and assessment criteria

Num	Criteria/Sub-criteria	Assessment Criteria		
		Class	Recovery Qualification	
1	Land Condition (40)			
	1.1	Critical Land Percentage (20)	≤ 5	Very Low
			5 < CLP ≤ 10	Low
			10 < CLP ≤ 15	Moderate
			15 < CLP ≤ 20	High
			CLP > 20	Very High
	1.2	Vegetation Coverage Percentage (10)	80 < VCP ≤ 100	Very Low
			60 < VCP ≤ 80	Low
			40 < VCP ≤ 60	Moderate
			20 < VCP ≤ 40	High
			VCP ≤ 20	Very High
	1.3	Erosion Index / EI (10)	EI ≤ 0.5	Very Low
			0.5 < EI ≤ 1	Low

Num	Criteria/Sub-criteria	Assessment Criteria	
		Class	Recovery Qualification
	Land and Plants Development Value (CP)	1 < EI ≤ 1.5	Moderate
		1.5 < EI ≤ 2	High
		EI > 2	Very High
		CP ≤ 0.1	Very Low
		0.1 < CP ≤ 0.3	Low
		0.3 < CP ≤ 0.5	Moderate
		0.5 < CP ≤ 0.7	High
		CP > 0.7	Very High
Water System Condition (20)			
2.1	Flow Regime Coefficiency FRC (5)	FRC ≤ 5	Very Low
		5 < FRC ≤ 10	Low
		10 < FRC ≤ 15	Moderate
		15 < FRC ≤ 20	High
		FRC > 20	Very High
2.2	Flow Coefficiency / C (5)	C ≤ 0.2	Very Low
		0.2 < C ≤ 0.3	Low
		0.3 < C ≤ 0.4	Moderate
		0.4 < C ≤ 0.5	High
		C > 0.5	Very High
2.3	Sedimentary Content (SC) (4)	SC ≤ 5	Very Low
		5 < SC ≤ 10	Low
		10 < SC ≤ 15	Moderate
		15 < SC ≤ 20	High
		SC > 20	Very High
2.4	Flood	Never	Very Low
		1x in 5 yr	Low
		1x in 2 yr	Moderate
		1x every year	High
		> 1 x / yr	Very High
2.5	Water Use Index (WUI)	WUI ≤ 0.25	Very Low
		0.25 < WUI ≤ 0.50	Low
		0.50 < WUI ≤ 0.75	Moderate
		0.75 < WUI ≤ 1.00	High
		WUI > 1.00	Very High
Socio-Economic Condition (20)			
3.1	Residents' Land Density in Agricultural Land Availability Index (10)	LAI > 4	Very Low
		2 < LAI ≤ 4	Low
		1 < LAI ≤ 2	Moderate
		0.5 < LAI ≤ 1	High
3.2	Residents' Welfare (7)	RW ≤ 5	Very Low
		5 < RW ≤ 10	Low
		10 < RW ≤ 20	Moderate
		20 < RW ≤ 30	High
		RW > 30	Very High
3.3	Norm Existence & Enforcement of Natural Resources Pro-Conservativist	Kelas 1	Very Low
		Kelas 2	Low
		Kelas 3	Moderate
		Kelas 4	High
		Kelas 5	Very High
BUILDING INVESTMENT (10)			
4.1	City Classification (5)	None	Very Low
		Small Town	Low
		Municipality	Moderate
		Major Cities	High
		Metropolitan	Very High
4.2	Waterworks Investment Qualification (5)	0 < WI ≤ Rp.15 M	Very Low
		Rp.15 < WI ≤ 30M	Low
		Rp.30 < WI ≤ 45M	Moderate
		Rp.45 < WI ≤ 60M	High
		WI > Rp. 60M	Very High
Space Utilization			
5.1	Protected Area (5)	PTH > 70%	Very Low
		45 < PTH ≤ 70 %	Low
		30 < PTH ≤ 45%	Moderate
		15 < PTH ≤ 30%	High
		PTH ≤ 15 %	Very High
5.2	Distinguished Area (5)	LKB > 70 %	Very Low
		45 < LKB < 70 %	Low
		30 < LKB < 45 %	Moderate
		15 < LKB < 30 %	High
		LKB < 15	Very High

According to the class criteria and assessment criteria applied at Gangsa watershed, it can be generated that the result of support capability condition is as following.

Table 9 Support capability condition on Gangsa watershed

Criteria/Sub-criteria	Fact Value	Value	Class	Score	Result
1. LAND CONDITION					
1.1 Critical Land Percentage	0.00%	CLP ≤ 5	Very Low	0.5	10

Criteria/Sub-criteria	Fact Value	Value	Class	Score	Result
1.2 Vegetation Coverage Percentage	19.73%	VCP ≤ 20	Very Poor	1.25	12.5
1.3 Erosion Index	0.46	0.30 < CP ≤ 0.50	Moderate	1	10
2. WATER SYSTEM CONDITION					
2.1 Flow Regime Coefficient (FRC)	133.75	FRC > 20	Very High	1.5	7.5
2.2 Annual Flow Coefficient (C)	0.64	C > 0.5	Very High	1.5	7.5
2.3 Sedimentary Content (SC)	77	SC > 20	Very High	1.5	6
2.4 Flood	>2x	More than once	Very High	1.5	3
2.5 Water Use Index (WUI)	2.552,67	1700 < WUI ≤ 3.400	Poor	1.25	5
3. SOCIO-ECONOMIC CONDITION					
3.1 Residents' Density	1.47	1.0 < LAIs ≤ 2.0	Moderate	1	10
3.2 Residents' Welfare	14.2	10 < RW ≤ 20	Moderate	1	7
3.3 Norm Existence & Enforcement	No Law	No Law	Poor	1.25	3.75
4. BUILDING INVESTMENT					
4.1 City Classification	824.828 individual	> 500.000 individual	High	1.25	6.25
4.2 Waterworks Value Classification	525.750.000.000	WI > 60 billion	Very High	1.5	7.5
5. SPACE UTILIZATION					
5.1 Protected Area	0.00%	KL ≤ 15	Very Poor	1.5	7.5
5.2 Distinguished Area	100.00%	KB > 70	Very Low	0.5	2.5
					106

Gangsa watershed support capability condition has the value of 106, consists of Land Condition criteria: Critical Land Percentage (10), Vegetation Coverage Percentage (12.5), Erosion Index of 10, in total 32.5. Meanwhile the water system condition consists of the Flow Regime Coefficient 7.5, Annual Flow Coefficient (C) 7.5, Sedimentary Content (SC) 6, Flood in score 3, while Water Use Index (WUI) is 5, in total 29. As for socio-economic condition, the Residents' Density in 10 points, Residents' Welfare at 7, Norm Existence and Enforcement is 3.75, in total 20.75 points. For Building investment criteria, it consists of City Classification at 6.25 and Building Value at 7.5, in total 13.75. The last criteria is Space Utilization, which are the Protected Area at 7.5 and Distinguished Area at 2.5, in total score 10.

The new watershed classification assessment (observing the class interval) is divided by 3. The *Maintained* classification is applied if the score is between ≤ 50 to ≤ 90. The *Improved* classification is applied if the score is between > 90 to ≤ 110. The *Recovered* classification is applied if the score is between > 110 until ≤ 130. Whereas the older watershed classification (one that does not pay attention to the class interval), the support capability is divided into 2 (two) watershed classification, which are the *Maintained* if the support capability lies on ≤ 100 (Good to Very Good category) and *Recovered* if the support capability is > 100 (Poor to Very Poor).

According to the analysis result, Gangsa watershed support capability is 106. In accordance to the old priority scale, Gangsa watershed belongs to Priority III for its support capability and rated as *Recovered*. This assessment is unsuitable with the actual condition. Hence,

it is needed to evaluate more about the watershed classification application by adding more thresholds or support capability categories. By using the new watershed support capability standard (the developed results), Gangsa watershed classification according to its support capability in scheme A is rated as Priority II, and according to scheme B it is rated as Priority III with classification: *Improved*. If compared to the interval class (the developed one) with the older classification (current situation), this Gangsa watershed undergoes a change in classification from *Recovered* to *Improved*.

4 Conclusion and advices

1. Watershed Classification criteria according to its class interval in support capability are as follows.
 - Watershed Support Capability Class Interval Score $50 \leq$ "Watershed Support Capability" ≤ 90 rated as watershed classification of *Maintained*.
 - Watershed Support Capability Class Interval Score ≤ 90 "Watershed Support Capability" ≤ 110 90 rated as watershed classification of *Improved*.
 - Watershed Support Capability Class Interval Score ≤ 110 "Watershed Support Capability" ≤ 150 90 rated as watershed classification of *Recovered*.
2. Urgency levels of watershed management according to its class interval in support capability are as follows.
 - Scheme A (first)
 - Watershed Support Capability Class Interval Score $50 <$ "Watershed Support Capability" ≤ 90 rated as (Urgency) Priority III.
 - Watershed Support Capability Class Interval Score $90 <$ "Watershed Support Capability" ≤ 110 rated as (Urgency) Priority II.
 - Watershed Support Capability Class Interval Score $110 <$ "Watershed Support Capability" ≤ 150 rated as (Urgency) Priority I.
 - Scheme B (second)
 - Watershed Support Capability Class Interval Score $50 \leq$ "Watershed Support Capability" ≤ 70 rated as (Urgency) Priority V.
 - Watershed Support Capability Class Interval Score $70 <$ "Watershed Support Capability" ≤ 90 rated as (Urgency) Priority IV.
 - Watershed Support Capability Class Interval Score $90 <$ "Watershed Support Capability" ≤ 110 rated as (Urgency) Priority Urgency III.
 - Watershed Support Capability Class Interval Score $110 <$ "Watershed Support Capability" ≤ 130 rated as (Urgency) Priority Urgency II.
 - Watershed Support Capability Class Interval Score $130 <$ "Watershed Support Capability" ≤ 150 rated as (Urgency) Priority Urgency I.
3. Gangsa watershed support capability scored 106, consists of 32.5 from Land Condition, 29 from Water System, 20.75 from Socio-economic, 13.75 from Building Investment, and lastly 10 points from the final criteria Space Utilization.
4. According to class interval (developed results), the Gangsa watershed is counted in the Moderate classification (*Improved*). The urgency level of

management according to the support capability, the urgency level is counted into the Priority II (Scheme A) and urgency level in Priority III (Scheme B).

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