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Regional Case Study

Determination of Reservoir Ecosystem Status in Cimahi City Government Office

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Abstract

Cimahi City continues to try to repair the damaged reservoir to function optimally as a raw water reservoir. This effort requires identifying the status of the reservoir ecosystem by assessing three standard criteria: aquatic, boundary, and terrestrial quality status. Two methods were carried out: field observation and laboratory research. The field observations are observations and interviews, determining the water sampling point and water sampling, and aerial photography for mapping surveys. The parameters of chlorophyll-A, algae, total nitrogen, and total phosphate were analyzed for the laboratory research. Based on research, the status of aquatic is in the threatened-destruction category because trophic level includes hyper-eutrophic, moderately polluted water quality, low biodiversity, and loss of food webs. The quality of the boundary ecosystem is in the damaged category because >25% of the area of the boundary is a settlement, and there is the disposal of domestic waste that enters the reservoir through canals. The quality of terrestrial ecosystems is in the threatened-damaged category because the land vegetation in the water catchment area is low, and there is an average annual siltation of ≥2% of the depth of the reservoir. It was concluded that management must be carried out in the water catchment area.

Keywords: Ecosystem status; hypereutrophic; pollution index; trophic status

1. Introduction

A reservoir is a water conservation building in the form of a river basin or water flow from the landfill, rockfill, concrete, and masonry that can hold and store water for various purposes (Ministry of Environment and Forestry, 2008). Pollution of reservoirs has occurred in all parts of Indonesia. This is one of the problems the government faces because the reservoir has a vital function, namely as an alternative source of raw water. Reservoirs will be challenging to restore if polluted and damaged; it takes a long time to fix them at a high cost (Rahim et al., 2022 and Wardhani et al., 2023). The same incident occurred in Cimahi City. Existing reservoirs have been damaged, so they are not functioning optimally; one is the reservoir in the Cimahi City Government Office. This reservoir is located in the Cimahi City Government Office Complex, Cibabat District, Cihanjuang Village, at coordinates S: 06°52'10.7" E: 107°33'17.6". The area of the reservoir is 0.036 Ha and has a volume of 1,333.5 m^3 (Cimahi Regional Environmental Management Performance Information Document, 2020). The function of the reservoir in Kota Cimahi is a place to store raw water and a means of permeating water (Regional Environmental Management Performance Information Document, 2020). The quality and quantity of groundwater in Cimahi City, which continues to decrease (Wardhani et al., 2021), will be helped by the seepage of water from the existing reservoir.

This study aims to analyze the reservoir ecosystem's quality status based on the assessment standards issued by the Indonesian Ministry of Environment in 2008 concerning guidelines for managing

lake ecosystems (Ministry of Environment and Forestry, 2008). The quality status of the analyzed reservoir ecosystem can be used as a reference for further research regarding the analysis of lake ecosystem management, both in Indonesia and on an international scale. The standard determines ecosystem quality based on the aquatic, boundary, and terrestrial quality status. The research results serve as a determinant of the management of the reservoir. The assessment results concluded that the reservoir ecosystem's condition was included in the good, threatened, and damaged categories. The research results are valid as primary data for planning rehabilitation so that the reservoir can be used optimally.

Research on reservoirs/lakes has been carried out a lot in a similar type which has been carried out, namely Rawapening Lake, by considering sedimentation from the water catchment area (Nugroho, 2022). Heavy metal pollution in the Saguling Reservoir affects the reservoir's function as a fishery cultivation area (Wardhani et al., 2018 and Wardhani et al., 2023). Research on water quality in the tropics results from human activities in the water catchment area (May et al., 2021). Analysis of the water quality of Swamp Kalong (Widyawati et al., 2022), Rawa Besar (Lukiyansah et al., 2020), Cisangkan River (Rosmeiliyana and Wardhani, 2021), Ciseupan Resevoir (Wardhani and Apsari, 2023), West Nusa Tenggara Province Rivers (Wardhani et al., 2023), and Pergau Reservoir (Samsudin et al., 2020) proves that human activities in the water catchment area affect the condition of the reservoir. Previous research on reservoirs has not discussed the entire reservoir ecosystem status, which refers to the 2008 State Ministry of Environment concerning Guidelines for Management of Lake Ecosystems. This research is essential because it thoroughly examines all the parameters that affect the quality of the reservoir. The quality status of the reservoir ecosystem is assessed by assessing the standard criteria for damage to three aspects, namely the quality status of aquatic, boundary, and terrestrial.

2. Methods

2.1. Determination of aquatic ecosystem status

Determining the quality status of aquatic ecosystems is conducted to analyse trophic status, water quality status, biodiversity, food webs, aquatic plant cover, algae/blue algae presence, and cultural fishery feed waste. Criteria for assessing the damage status of aquatic ecosystems are presented in Table 1. Tropical status assessment by category is shown in Table 2.

Table 1. Criteria for assessing the damage status of aquatic ecosystems

Parameter	Ecosystem status		
	Good	Threatened	Damaged
Tropic status	Oligotrophs-Mesotrophs	Eutrophic	Hypereutrophic
Water quality status	Unpolluted	Moderately polluted	Heavily polluted
Biodiversity	There are still endemic and native species of fauna/flora	Reduction of endemic and native fauna/flora species	Loss of endemic and original fauna/flora species, many introduced/invasive species were found
Food web	Balanced Trophic Levels	The trophic levels are unbalanced	There are no trophic levels
Aquatic plant cover	Controlled does not spread or interfere with the lake's function.	It is less controlled and disrupts the function of the lake	It spreads uncontrollably, seriously disrupting the function of the lake
Microcystis	Slight	Moderate	Many

Parameter	Ecosystem status		
	Good	Threatened	Damaged
Aquaculture feed waste	The amount of fish production and feed use follows the lake's capacity and permits.	The amount of fish production and feed use exceeds the funds' capacity but fulfills permits.	Cultivation activities and feed use are out of control, do not fulfill permits, and do not meet the lake's capacity.

Table 2. Categories of lake trophic status UNEP-ILEC Method

Trophic status	Average content of total N (µg/l)	Average level of total P (µg/l)	Average Chlorophyll-a level (µg/l)	Average brightness (m)
Oligotrophic	≤ 650	< 10	< 2.0	≥ 10
Mesotrophic	≤ 750	< 30	< 5.0	≥ 4
Eutrophic	≤ 1,900	< 100	< 15	≥ 2.5
Hypertrophic	> 1,900	≥ 100	≥ 200	< 2.5

Assessment of aquatic ecosystems was obtained through field observations and water sampling, carried out on September 9, 2022. Sampling refers to the Indonesian national standard 6989.57:2008 surface water sampling method. Trophic status research was carried out by testing two parameters: Total Nitrogen and Total Phosphate. The total Nitrogen analysis method refers to Standard Methods for The Examination of Water and Wastewater 23rd Edition 2017 (APHA) using the 2017 APHA-4500-Norg-B method. Total Phosphate testing was carried out using the 2017 APHA-4500-P-B-D method. Sample examination was carried out in the water quality laboratory of the Bandung Institute of Technology. The study results were compared with the trophic status categories presented in Table 2. Testing for chlorophyll-a parameters refers to the Indonesian national standard 06-4157-1996 concerning testing chlorophyll A levels of phytoplankton in water with a spectrophotometer. The examination was conducted at the Ecology Laboratory of Padjadjaran University, Bandung City—brightness measurement using a Secchi disk. Table 2 presents the method of determining Lake trophic status categories based on UNEP-ILEC.

Calculation of water quality status uses secondary data obtained from the Cimahi City Environmental Service in 2022. Quality standards refer to Government Regulation Number 22 of 2021 concerning Implementing Environmental Protection and Management, class 1 attachment VI. There are 23 parameters analysed, namely temperature, pH, DO, DHL, free chlorine, TSS, TDS, colour, ammonia, chloride, sulfate, nitrate, nitrite, fluoride, dissolved Fe, dissolved Mn, dissolved Zn, dissolved Cu, Cr (VI), total phosphate, cyanide, sulfide, total detergent (MBAS). BOD, COD, oils and fats, and phenols. Determination of water quality status uses the Pollutant Index calculation method. This method shows the classification of the reservoir's water quality, whether in good condition, lightly polluted, moderate, or heavily polluted. The pollutant index (PI) classification assessment is divided into four, namely the classification index assessment $0 \leq PI \leq 1$, which meets quality standards (good condition); index $1 < PI \leq 5$, namely lightly polluted; index $5 < PI \leq 10$, namely moderately polluted, and $PI > 10$, namely heavily polluted (Ministry of Environment Decree No. 115, 2003).

Assessment of the parameters of biodiversity, food webs, and whether fish farming is in the reservoir using field observations and interviews with the reservoir managers. Aquatic plant cover is assessed to determine the distribution of aquatic plants that have the potential to disrupt the function of the reservoir by conducting field observations. Algae/blue algae are considered for the presence of microcystins in reservoirs that can interfere with the function of reservoirs by taking water samples to determine the type of algae by observing the ecology laboratory at Padjadjaran University.

2.2. Determination of boundary ecosystem status

The process of determining the status of a boundary ecosystem begins with choosing the boundaries of the border. Based on the Regulation of the Minister of Public Works and Public Housing No. 28 of 2015 concerning the establishment of the river and lake boundary lines, the lake boundary line is determined to surround the reservoir at a minimum of 50 meters from the edge of the highest water level that has ever occurred (the boundary of the reservoir body). The reservoir's perimeter in the photo using the DJI 4 Phantom Pro drone was taken with a radius of 100 meters around the reservoir. The assessment of the bordering ecosystem consists of observing whether buildings are on the boundary, plantation and rice field activities, and waste disposal. Assessment criteria for the bordering ecosystem are presented in Table 3. The assessment of the bordering ecosystem is only through buildings on the border and the disposal of domestic wastewater, where the reservoir is not used for hydroelectric raw water intake.

Table 3. Criteria for the assessment of the damage status of the boundary ecosystem

Parameter	Ecosystem status		
	Good	Threatened	Damaged
Lake boundary	No buildings	There's been a bit of development going on	Lots of buildings
Waste disposal	No waste disposal	There is waste disposal and no water pollutant control system, but it does not exceed the capacity of lake water pollutants.	There is sewage disposal, and water pollutant control systems do not exist or are inadequate and have exceeded lake water.

2.3. Determination of terrestrial ecosystem status

The terrestrial ecosystem is one type of ecosystem element whose management area is in the water catchment area. Determination of the status of terrestrial ecosystems based on vegetation cover in the catchment area, the impact of lake siltation, and waste disposal, as presented in Table 4.

Vegetation cover parameters on catchment area land were determined to determine the reduced land cover area at the research location. This could affect land use change by comparing land vegetation cover data 2018 (secondary data) using maps sourced from DEM 2022 data with map data—aerial photo mapping. Lake siltation parameters were evaluated using field observation and interviews with reservoir managers.

Table 4. Criteria for assessing the status of damage to terrestrial ecosystems

Parameter	Ecosystem status		
	Good	Threatened	Good
Vegetation cover on catchment area land	< 75%	30-75 %	< 30%
Waste disposal	There is waste disposal and a water pollution control system, which is following the capacity to accommodate lake water pollution.	There is waste disposal and no water pollution control system, but it does not exceed the capacity of the lake water pollution.	There is waste disposal, and the water pollution control system is not flawed and has exceeded the capacity to accommodate lake water pollution.

3. Result and Discussion

The reservoir located in the Cimahi City Government Office is a building that functions as a water storage building and was operational in 2015 (Cimahi Regional Environmental Management Performance

Information Document, 2020). This reservoir has an area of 0.036 Ha and a volume of 1,333.5 m^3. Based on the results of the mapping of the reservoir border in 2022 using the DJI 4 Phantom Pro drone, which was taken with a coverage of 100 meters of the reservoir border, there are 2.19 hectares of gardens, 1.14 hectares of settlements, 0.53 hectares of buildings, 0.03 hectares of cemeteries, and a parking area of 0.52 Ha. This land use causes the reservoir to become polluted, so rehabilitation must be carried out to restore the function of the reservoir as a place to store water (Cimahi Regional Environmental Management Performance Information Document, 2020).

3.1. Determination of aquatic ecosystem status

The tropical status of the reservoir was assessed by knowing the parameters of Total Phosphate, Total Nitrogen, Chlorophyll-a, and Brightness. The parameter test results for determining the trophic status of the reservoir are listed in Table 5. Based on the results of calculations using Table 2, the tropical status of the reservoir is included in the hypereutrophic category.

Table 5. Recapitulation of aquatic ecosystem assessment

Parameter	Ecosystem status			Note
	Good	Threatened	Damaged	
Trophic status			✓	Hypereutrophic
Water quality Status		✓		Moderate Polluted
Biodiversity			✓	Loss of endemic and original fauna/flora species, many introduced/invasive species were found.
Food web			✓	There are no trophic levels.
Aquatic plant cover	✓			Controlled does not spread or interfere with the lake's function.
Microcystis	✓			Slight

Table 6. Parameter test results for determining the trophic status

Parameter	Unit	Test results
Total phosphate	µg/l	248
Total nitrogen	µg/l	2.840
Chlorophyll-a	µg/l	258
Brightness	m	0.388

The hypereutrophic category is water where algae are abundant, and the waters are in anoxic conditions that can cause mass fish death with very high nutrient levels (Ariyani et al., 2019). Hypereutrophs also show an increase in chlorophyll-a content and phosphate concentrations, which can cause the growth of water hyacinth, which, if left unchecked, can cause silting processes and decrease the concentration of dissolved oxygen in water (Noor, 2019; Wardhani and Hapsa, 2022). The hypereutrophic category indicates that increased levels of Nitrogen and Phosphorus have heavily polluted the water. Nitrogen in the water shows that agricultural activities and land processing carry out fertilization activities, so the flow carries these nutrients into the reservoir. Domestic waste from human activities also triggers high nitrogen levels in water (Harianja et al., 2019; Wardhani and Sugiarti, 2022). The high level of Phosphate in the water is caused by the existence of the agricultural and livestock sectors in the upper reaches of the river and also the entry of waste from domestic and industrial activities carried by the flow of river water to the reservoir so that this can indicate high levels of Phosphate in the reservoir water (Effendi et al., 2018).

The results of calculating the water quality status concluded that there was moderate pollution. The causes of pollution are BOD, COD, total phosphate, free chlorine, oil and grease, and phenol, which

do not meet quality standards. Poor water quality is caused by pollution originating from the catchment area (Wardhani and Primalaksono, 2022). The Cimahi River is this reservoir's primary water source, and the river's quality has been polluted from upstream (Wardhani and Primalaksono, 2022). The following parameter for assessing the quality status of aquatic ecosystems is biodiversity. This parameter is damaged because no endemic flora, fauna, or food web exists. Aquatic plants do not cover the condition of the reservoir because the manager routinely cleans it.

Phytoplankton or macroalgae with a type of blue algae (microcystins) is used for plankton analysis because the algae can interfere with the aesthetics of the lake/reservoir and exacerbate the situation with eutrophication (Sulastri et al., 2020). 13 types of phytoplankton live in the reservoir, namely: *Euglena sp, Nitzschia sp, Trachelomonas sp, Surirella sp, Gyrosigma sp, Fragilaria sp, Melosira sp, Pinnularia sp, Synedra sp, Navicula sp, Diatoms sp, Peridinium sp, and Symbela sp.* There are microcystins in the waters, indicating that the ecosystem status has been damaged, but not found in the reservoir microcystins. However, its trophic status is included in the hypereutrophic category. Mycrocystis in water is influenced by the optimum water temperature range of 28°-30°C (Sulastri et al., 2020). The temperature of the reservoir in 2022 will be 20°C. The recapitulation of aquatic ecosystem assessments is presented in Table 6.

3.2. Determination of boundary ecosystem status

Only two parameters can be analysed to determine the status of the bordering ecosystem: the condition of buildings and waste disposal at the lake border. This reservoir is not utilized for hydroelectric power generation and raw water extraction. The lake riparian assessment criteria for good status is no buildings, threatened status is buildings ≤ 25%, and damaged status is buildings > 25%. Table 7 presents changes in land use at the embankment boundaries in 2018 and 2022.

Table 7. Changes in land use at the reservoir border

Land use	2018		Land use	2022	
	Wide (Ha)	Percentage (%)		Wide (Ha)	Percentage (%)
Reservoir	0.040	0.964	Reservoir	0.040	0.964
Settlement	0.270	6.506	Settlement	2,190	52,951
Ricefield	1.040	25.060	Garden	1.890	45.542
field	2.800	67.470	Cemeteries	0.030	0.723
Total	4.150	100%	Total	4.150	100%

Table 8. Recapitulation of boundary ecosystem assessments

Parameter	Ecosystem status			Note
	Good	Threatened	Damaged	
Lake boundary			✓	Lots of development (> 25%)
Waste disposal			✓	There is sewage disposal, and water pollutant control systems do not exist or are inadequate and have exceeded lake water.

Table 7 shows settlements on the embankment boundary area increased from 6.506% to 40.421%. This increase was due to the location of the reservoir being in the centre of the city government with high population growth. In 2018, the embankment border land was utilized as a residential area of 0.27 Ha, 1.04 Ha of rice fields, and fields/fields of 2.8 Ha. As time passed, there was a change in land use on the border in 2020 of 1.67 hectares of settlements, 1.89 hectares of gardens, 0.03 hectares of cemeteries, and 0.52 hectares of parking lots.

Based on this, the number of buildings on the uterine border increased to > 25%. Based on the results of observations, there are no pipes/drains that enter the reservoir but are affected by the discharge

from the Cimahi River that enters the reservoir. A summary of the assessment of the bordering ecosystem is presented in Table 8.

3.3 Determination of aquatic ecosystem status

Table 9. Vegetation land cover in the catchment area

2018			2020		
Vegetation type	**Wide (Ha)**	**Percentage**	**Vegetation type**	**Wide (Ha)**	**Percentage**
Field	2.810	84.894	Garden	1.930	58.308
Ricefield	0.150	5.068	Cemeteries	0.030	1.531
Total vegetation area	2.960	89.962	Total vegetation area	1.960	59.839
Total catchment area	3.310	100	Total catchment area	3.310	100

Table 10. Recapitulation of terrestrial ecosystem assessments

Lake parameters	Ecosystem status			Note
	Good	**Threatened**	**Damaged**	
Land vegetation in the catchment area		✓		30-75%
Lake silting effects			✓	Silting average per year ≥ 2% of the depth of the lake
Disposal of waste in river bodies			✓	There is waste disposal, and the water pollution control system has exceeded the capacity to accommodate lake water pollution.

Two parameters cannot be further analysed: the river regime coefficient and soil erosion in the catchment area. River regime coefficients cannot be analysed because the research was only conducted in one season. Erosion of the water catchment area cannot be calculated due to data limitations.

Based on the mapping results on the DEM map 2018, the water catchment area is 3,310 ha, with 89.43% vegetation land cover (2,810 Ha)—vegetated land in the form of moor/fields and paddy fields. From 2018 to 2022, land vegetation decreased by 30.21% to 59.210%, with types of vegetation in the form of gardens and public cemeteries. The calculation results are presented in Table 9. Terrestrial ecosystem status for the parameters of land vegetation cover in the water catchment area is included in the damaged category because the percentage of land vegetation cover in 2022 is 30-75%.

The reservoir in the Cimahi City Government Office was built in 2015 with a depth of 3 meters. This reservoir is included in the shallow lake category because it has a depth of < 10 m (Wardhani et al., 2023). In 2022, the reservoir will have a depth of 60 cm, which illustrates siltation of 0.343 m/year or 11.43% per year. Based on the results of field observations, the reservoir has been used as a pre-sedimentation reservoir, so it has silted up due to sediment in the reservoir. The average yearly siltation is ≥ 2% of the lake's depth, which is included in the damaged status. Waste disposal at the reservoir in the Cimahi City Government Office comes from the flow carried into the reservoir from the Cimahi River (Wardhani and Primalaksono, 2022). The types of waste that enter the Cimahi River are domestic waste, industry, plantations, and rice fields (Wardhani and Primalaksono, 2022; Wardhani et al.,2023). Insufficient pollution control has been carried out so that the status of terrestrial ecosystems in waste disposal is damaged. A summary of the assessment of terrestrial ecosystems is presented in Table 10. Table 11 show an overview of the evaluation of the quality of reservoir ecosystems.

Table 11. Recapitulation of reservoir ecosystem assessment in Cimahi City government offices

Number	Aquatic ecosystem parameter	Status
1	Trophic status	Damaged
2	Water quality status	Threatened
3	Biodiversity	Damaged
4	Food web	Damaged
5	Aquatic plant cover	Good
6	Algae/blue algae	Good
	Boundary Ecosystem	
1	Boundary reservoir	Damaged
2	Waste disposal	Damaged
	Terrestrial Ecosystem	
1	Vegetation cover on catchment area land	Threatened
2	The impact of silting reservoir	Damaged
3	Waste disposal	Damaged

4. Conclusions

Based on the results of the study, it was concluded that the aquatic ecosystem of the reservoir is included in the endangered-damaged category due to its trophic status, including the hypereutrophic type caused by high levels of nitrogen and phosphorus, which indicates that the reservoir has experienced pollution originating from the water catchment area. This correlates with the water quality status, which is included in the moderately polluted category. Parameters that did not meet quality standards were BOD, COD, Total Phosphate, Free Chlorine, Oil and Fat, and Phenol. Poor water quality causes biodiversity, including damaged status and no food web in the reservoir. Parameters of border ecosystem status that can be analysed are buildings and waste disposal. There was an increase in land use for settlements of 20.964%, and there was the disposal of wastewater through the Cimahi River, the primary source of this reservoir. Parameters of terrestrial ecosystem status that can be analysed are land vegetation in water catchment areas, siltation, and waste disposal. In 2022, the vegetation land cover in the water catchment area was 59.21%. There is silting of the reservoir at 11.43% per year, so the silting parameter is damaged. This condition requires efforts to manage the riparian and water catchment areas so that the waste does not accumulate in the reservoir.

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