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EVALUATION OF WATERSHED CARRYING CAPACITY FOR WATERSHED MANAGEMENT

(A CASE STUDY ON BODRI WATERSHED, CENTRAL JAVA, INDONESIA)

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OUTLINE

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Introduction

Watershed Management is a human action aimed at ensuring the use of watershed resources, through an integrated ecosystem approach [*FAO, Watershed management in action – lessons learned from FAO field projects* (*Rome, 2017*)], to maintain the sustainability of existing resources within the watershed by conserving well-balanced quantities of water, soil, vegetation and other natural resources [*S. R. Ahn and S. J. Kim, Assessment of Integrated Watershed Health Based on The Natural Environment, Hydrology, Water Quality, and Aquatic Ecology, Hydrol. Earth Syst. Sci.* ***21****, 5583–5602* (*2017*)].

- **DEFINITION WATERSHED**

  Watershed is a land area that is a unity of ecosystems with rivers and tributaries that function to accommodate, store, and drain water from rainfall to the lake or sea naturally, the boundary on land is a topographical separator and boundaries in the sea up to irrigation areas that are still affected by land activities. (Law No. 7/2004 Ps 1)

- **We hope to achieve IDEAL WATERSHED (indonesian)**

  - **Able to guarantee the sustainability of the watershed (ensuring high productivity, low erosion / sediment, & watershed functions as a water store can provide a fairly high "water yield" through out the year)**
  - **Able to maintain equal distribution of farmer's income (equity)**
  - **Able to provide high land productivity**
  - **Able to maintain the watershed sustainability of the shocks that occur (recilient)**

CONTINUE.....

This study aimed at evaluating the watershed classification dealing with its carrying capacity as a planning fundamental in the watershed management

What Is a Healthy Watershed? (Environmental Protection Agency, Office of Water, Washington D.C., 2011)

Ideally, a healthy watershed has the ability to provide the following:

- Habitat of sufficient size and connectivity and hydrologic (surface and subsurface) connectivity to sustain native aquatic and riparian species;
- Native vegetation and green infrastructure (network of habitat hubs and corridors) in the landscape to maintain natural hydrology (including recharge of groundwater) and nutrient and organic matter inputs essential to maintaining aquatic ecosystem functions;
- Biotic refugia or critical habitat (e.g., deep pools, seeps and springs, cold water tributary junctions for survival during droughts all sustained by sufficient water levels in lakes and instream flows in rivers);
- Natural hydrology (e.g., flow regime, lake water levels) that supports aquatic species and habitat;
- Natural transport of sediment and stream geomorphology that provide a natural habitat;
- Natural disturbance regimes (e.g., floods and fire) on which biota depend;
- Water quality that supports aquatic and riparian biotic communities and habitat; and
- Healthy, self-sustaining aquatic and riparian biological communities.

❑ PROBLEMS

1. **Most of Conditions of Watershed Not Understanding With Surprise Whether Are There Are Such or Healthy Watershed**
2. **Experiencing The Constraints In The Making Of The Activities Or The Program of The Next Stage (Because There Are No Previous Assessment of The Condition of Watershed)**

Method of data collection and analysis

2.1 Study area

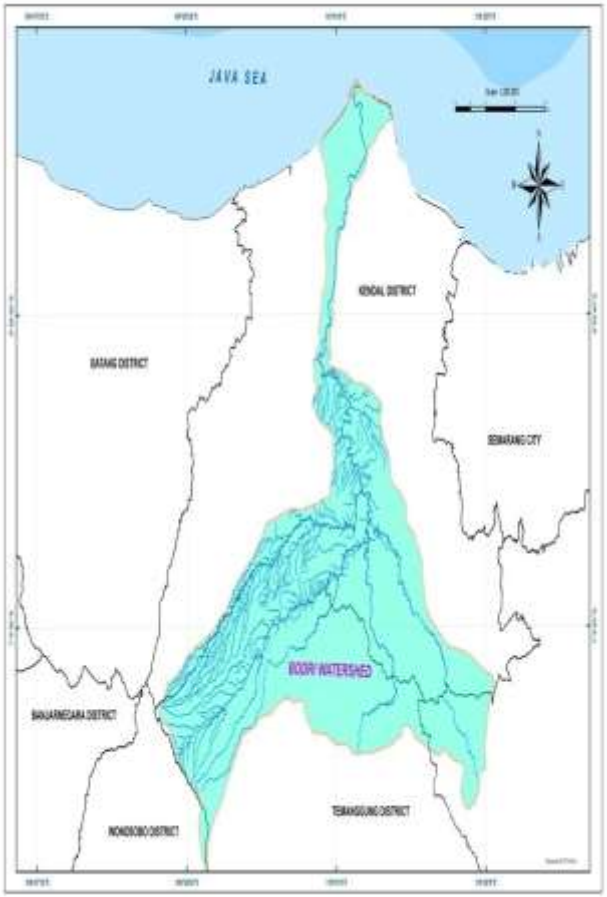


FIG.1

Study Bodri Watershed is situated on the coordinates of 109°09'00"-109°15'31" East and 06°51'47"-07°04'29" South. It covers a total area of 65,248.54 hectares (2.6% of the total area of *BPDAS Pemali Jratun*) and a total radius area of 599.90 km^2. The major upstream of Bodri Watershed is 87-kilometer long River Bodry (Fig.1).

Method of data collection and analysis

Sampling technique

Instruments used during the research observation consisted of Watershed Surveillance Station for collecting hydrological data, Global Positioning System (GPS) for determining geographical coordinate points where samples were collected, digital camera for on site documentation, ArcView software for landsat imaging and digital maps interpretation, and a set of computer for data processing and analysis.

Method of data collection and analysis

During the survey and data collection the study made use of the following equipments:

- land coverage maps,
- land use/data maps,
- watershed/sub-watershed maps (i.e., watershed/sub-watershed, river, land, topography/contour),
- adminstrative map,
- land capacity class map,
- hydrological data (on debit, rainfall, sediment, and surface runoff).

Method of data collection and analysis

Data processing was performed in several stages, as the followings: data collection, data selection, and data tabulation. Each data were tabulated according to land (critical land, vegetation covering, and land appropriateness) and hydrology. The field observation was done in concert with related institutions (Local Development Planning Board, Municipal Office of Public Works for water resources and spatial management, Municipal Office of Environment, Provincial Office of Environment and Forestry, Center for Statistics on Population and Citizenship Records, and Municipal Office of Social Affairs) of Temanggung and Kendal Regencies. The data analysis for evaluating the watershed carrying capacity was performed using the Microsoft Office Excel,

Criteria/sub-criteria of bodri watershed carrying capacity

The five-stage integrated evaluation of the Bodri Watershed carrying capacity (is the watershed capacity for realize the sustainability and harmony of the ecosystem and increasing the utilization of natural resources for human beings and other living things in a way sustainable) was performed to find out the criteria according :

- land condition,
- water management,
- soci-economic aspect,
- building investment,
- and area spatial use.

Criteria/sub-criteria of bodri watershed carrying capacity

3.1 Land condition

3.1.1 Critical area percentage

The critical area percentage was determined according to the data analysis for the critical land [Peraturan Menteri Kehutanan Republik Indonesia Nomor : P. 61 /Menhut-II/2014 tentang Monitoring Dan Evaluasi Pengelolaan Daerah Aliran Sungai (in Indonesian)] and subject to an onsite ground check for updated and existing result, in which only those with critical and severely critical conditions were included.

The critical area of Bodri Watershed covered 6,245.46 ha (or 6.34% of the total area 65,248.54 ha). It indicated that the critical area at Bodri Watershed fell into Low classification (relatively good). The critical area had a major impact on the Bodri River Stream because it had a weight score of 20%. The critical area is defined as an area suffering from damage, causing loss of function to the expected limit [Peraturan Direktur Jenderal Bina Pengelolaan Daerah Aliran Sungai Dan Perhutanan SosiaL Nomor : P. 4/V-Set/2013Tentang Petunjuk Teknis Penyusunan Data Spasial Lahan Kritis (in Indonesian)]. In conclusion, the areas surrounding Bodri Watershed remained highly productive with a strong carrying capacity to provide the maximum results using

Criteria/sub-criteria of bodri watershed carrying capacity

3.1.2 Vegetation covering percentage

The percentage followed the requirement of Directorate General of Planology of the Ministry of Forestry [SK Dirjen RRL No. 041/Kpts/V/1998 tanggal 21 April 1998 tentang Kriteria Lahan Kritis (in Indonesian)] and was subject to an onsite ground check. The vegetation covering of Bodri Watershed had a total permanent vegetated area of 6,783 ha (39.28% of the total area). In other words, it was classified Poor. These data concluded that the watershed lacked of permanent vegetation due to change in land function, i.e. for seasonal cultivated crops or other purposes. A good watershed must have the vegetation covering index of > 70%.

Criteria/sub-criteria of bodri watershed carrying capacity

3.1.3 Erosion index

In terms of erosion index, which deals with the vegetation management and conservation treatment, Bodri Watershed had an erosion index of 0.38 or IE < 0.5. In other words, it was classified Moderate. Such condition indicated that the area was simultaneously managed but in a very conventional manner and hereditary, in which the techniques were surpassed through generations. The land conservation treatment such terrace and SPA only applied to technical and wet rice fields.The crop pattern management took place by season and agricultural life and management remained traditional and local. Furthermore, older generations dominated the agricultural activities.

Criteria/sub-criteria of bodri watershed carrying capacity

3.2 Water management

3.2.1 Stream regime coefficient

Stream regime coefficient is a Q max-Q min ratio obtained from SPAS. The KRA score for Bodri Watershed was 215.22, included in a High classification (KRA > 110). In other words, this watershed had a quite unstable stream (flood during rainy season; low water debit during dry season). The watershed storages were not quite capable of storing the rain water into the ground, causing floods. Therefore, during the dry season the storage could not afford to supply the water.

Criteria/sub-criteria of bodri watershed carrying capacity

3.2.2 Annual stream coefficient

The high annual stream coefficient indicates poor capacity of the watershed to absorb the rain water into the ground due to poor vegetation covering, plain slope, soil type, and land conservation treatment. Bodri Watershed had annual stream coefficient of 0.1, classified Low. However, its stream regime coefficient was considered High, indicating that the rain water absorbed into the ground were not stored due to plain slope at the river downstream. Putih and Lutut sub-downstream had a grumusol soil characteristic, which, according to a research by BPPT Bogor, was not responsive to erosion and not capable of storing the water because it is composed of limestones.

Criteria/sub-criteria of bodri watershed carrying capacity

3.2.3 Sediment content

A good sedimentation occurs in areas or branches of the main river due to soil deposits from erosion and sedimentation. The sediment content of Bodri Watershed was calculated using a USLE equation by determining A score (erosion alert) of each area unit of the watershed multiplied by SDR. The sediment of the watershed obtained was 24.37 (classified High because it was higher than 20). This high sediment caused the loss of soil layers. The major causes of the sedimentation were poor vegetation covering and plain slope at the river downstream, as well as poor conservation treatment and change in land use at the river downstream.

Criteria/sub-criteria of bodri watershed carrying capacity

The high sedimentation rates were evident at Lutut (61.17) and Loging (44.2) sub-watersheds. These two sub-watersheds had their upstream in Temanggung Regency.

3.2.4 Floods

Floods occurred at all sub-watersheds with intensity of twice annually (even four times at the extreme condition). The floods did not only occur at the major rivers, but also at the sub-upstream. They could have been accommodated by the river trenches, but not every river had such capacity. The historical records indicate that the worst River Bodri occurred in 2009 at the expense of local population and agricultural area in Pidodo Kulon and Pidodo Wetan Villages.

Criteria/sub-criteria of bodri watershed carrying capacity

River Lutut, River Putih, and River Logung, all were situated at the river upstream and wide and deep enough to supply and store the water, preventing the worsening floods. The extreme gradient of the river helped its stable water flow.

3.2.5 Water use index

The water index use of Bodri Watershed was 564 (< 1,700), classified severely Poor. The water indices of each sub-watershed were also poor (< 1,700). The very low water index indicates inability to supply the water for irrigation or daily need, i.e. drinking water, especially during the dry season. Artificial ponds, folders, or lakes are necessary to supply the water and to prevent the floods.

Criteria/sub-criteria of bodri watershed carrying capacity

As of the research period, there were only a few of water ponds provided by PT Zanzibar. However, Logung sub-watershed had the water index of 2,257 (> 1,700). The area was very fertile and covered Kaloran and Candiroto Districts. The study found 18 water supplies and storages in virgin forests, preventing the area from floods during the rainy season and the drought during the dry season.

Criteria/sub-criteria of bodri watershed carrying capacity

3.3 Socio-economic aspect

3.3.1 Population stress

The population stress of Bodri Watershed was relatively High (> 2). Such condition was found in all, but Bodri downstream, sub-watersheds. The Bodri downstream had a population stress of 1.43 (< 2), whereas the population stress of Bodri Watershed was 2.16. Such condition indicated that the local population greatly depended on the land sector to fulfill their daily living.

Criteria/sub-criteria of bodri watershed carrying capacity

The high population stress caused the land to be occupied simultaneously to produce. They did not give spare time for the land except during the dry season. Accordingly, the land became less fertile. Plants once cultivated by their ancestors, e.g. rosella and orok-orok, were no longer found. Inorganic fertilizers had dominated the agricultural activities, damaging soil structures due to excessive chemical contents. Conversely, Bodri downstream remained intact with the population stress of >2, in which 75% of the total area was plain and urban. The settlements grew fastly as the population grows in numbers. The low population stress indicated that at Bodri downstream the population did not only rely on the land sector.

Criteria/sub-criteria of bodri watershed carrying capacity

Instead, in this area there had been factories, offices, stores, and markets for alternative living of the local people. In addition, they also run service business.

3.3.2 Welfare

Population welfare is characterized by the high (or low) poverty rate at the watershed. The field observation found that the population welfare was high (poor) >30. Of 744,465 populations, 30.2% of them were still under poverty line. Of three sub-watersheds at Bodri Watershed, Putih sub-watershed had the highest welfare (23.3%). It was due to its natural condition. Putih sub-watershed had the upstream in Kaloran, Limbangan, Sukorejo, and Sumowono Districts.

Criteria/sub-criteria of bodri watershed carrying capacity

The road access in these areas was poor, made of combined concrete-macadam pavements. The poor road access did not necessarily mean that these areas were poorly treated by the local governments. Instead, it was due to harsh natural conditions. Distance from urban area, topography, and soil structure contributed to the damage of the road access, as the study found in Limbangan-Kedungboto-Cening route.

3.3.3 Law Enforcement

Law enforcement in land management closely relates to local culture. The rule of law is drafted to provided written term and condition towards the people treatment of the land and water conservation.

Criteria/sub-criteria of bodri watershed carrying capacity

The study did not found any rule of law enforced in the area of Bodri River Stream. Should there be any, it had not been put into practice. Interviews with village staff and officers revealed that they had already had rule of law but remained ineffective. However, in absence of written rule, the local people had already understood the benefit of planting trees, constructing terrace, and performing land conservation. Gotong royong (mutual work for mutual interest) has become the local code of conduct that was passed through generations. Gotong royong became the principle of problem-solving of the localities.

Criteria/sub-criteria of bodri watershed carrying capacity

3.4 Building investment

3.4.1 Urban classification

Bodri Watershed covered four regencies, i.e. Temanggung, Kendal, Semarang, and Wonosobo. The urban classification was approached by population size and area within the watershed. The data analysis concluded that urban areas within Bodri Watershed were classified Moderate. Where, the cumulative score was classified Large.

Criteria/sub-criteria of bodri watershed carrying capacity

3.4.2 Building investment value

The data analysis revealed that at Bodri Watershed there were several vital buildings necessary to be protected. They had been shortlisted, including large water dams with irrigation branches of 104 smaller dams and a larger dam. Government office buildings were also under inventory, as well as large factories. The investment value was estimated more than 60 billion of rupiah.

Criteria/sub-criteria of bodri watershed carrying capacity

3.5 Area spatial use

3.5.1 Conservation area

The data analysis resulted in as follows: 7,385.04 ha (11.31% of the total area) consisted of conservation area with 3,361.04 ha (45.51% of the total area) with vegetation covering classified Good. The vegetation covering within the conservation area in the Watershed is expected to be >70%.

Criteria/sub-criteria of bodri watershed carrying capacity

The establishment of conservation area is based on physical characteristic of the area and role in creating balanced water management, especially for Bodri Watershed. The conservation area also plays a significant role in storing and supplying the water for the watershed.

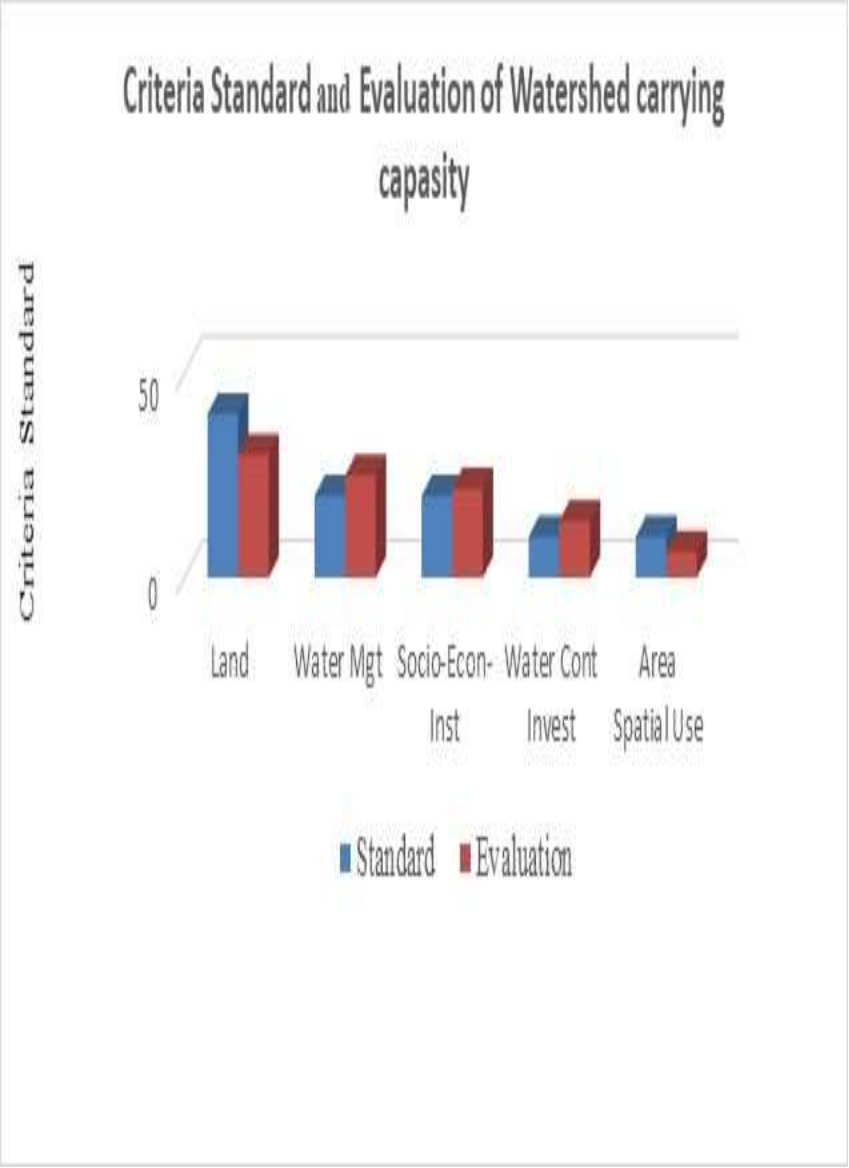
3.5.2 Cultivated area

Cultivated area at Bodri Watershed on the slope class 0-25% was 40,689.45 ha (70.32%). These data revealed that the cultivated area had been adequate. Cultivated area for seasonal crops/settlements was determined by a land unit with the slope of 8 per cent at the maximum rate with soils not prone to erosion.

Criteria/sub-criteria of bodri watershed carrying capacity

The land unit with the slope class 8-5 per cent with soils not prone to erosion, and slope class 15-25 per cent with soils slightly prone to erosion. Dry area dominated the composition of the cultivated area of the watershed. Management is necessary to anticipate problems related to water absorption, urban green area, water use management and groundwater intake, and urban area development, to mention some.

Bodri watershed carrying capacity



The evaluation of the watershed carrying capacity was performed in an integrated manner covering five criteria as follows: land condition 40%; water management condition 20%; socio-economic condition 20%; building investment condition 10%; and area spatial use condition 10%.

Bodri watershed carrying capacity

Table 1. Bodri watershed carrying capacity.

No	Criteria/Sub-criteria	Weight %	Fact Value	Value	Class	Score	Result (3x7)
1	2	3	4	5	6	7	8
1	Area condition	40					
	1.Critical area percentage	20	3.60%	PPLK ≤5	Very Low	0.5	10
	2.Vegetation covering	10	43.19%	40 < PPV ≤ 60	Moderate	1	10
	3.Erosion Index	10	0.38%	IE ≤ 0.5	Moderate	1	10
2	Water management condition	20					
	1.Stream regime coefficient (KRA)	5	215.22	KRA >110	Very High	1.5	7.5
	2.Annual stream coefficient (KAT)	5	0.1	KAT ≤ 0.2	Very Low	0.5	2.5
	3.Sediment content (MS)	4	24.37	MS >20	Very High	1.5	6
	4.Flood	2	>2 times	> 1 time	Very High	1.5	3
	5.Water use index (IPA)	4	564	IPA ≤ 1,700	Very Poor	1.5.	6
3	Socio-economic condition	20					
	1.Population stress (IKL)	10	2.16	2.0<IKL ≤4.0	High	0.75	7.5
	2.Population welfare (TKP)	7	30.2	TKP >30	Very Poor	1.5	10.5
	3.Law enforcement	3	n/a	n/a	Poor	1.25	3.75
4	Building investment	10					
	1.Urban classification	5	744.94	$>5x10^5$	High	1.25	6.25
	2.Water construction classification	5	1,185,735,400	IBA $>6x10^{10}$	Very High	1.5	7.5
5	Area spatial use	10					
	1.Conservation area	5	45.51%	45 <KL≤70	Good	0.75	3.75
	2.Cultivated area	5	70.32%	KB >70	Very Low	0.5	2.5
	Bodri Watershed Performance						96.7

The scores of the carrying capacity of the watershed were obtained from data analysis of each weight score of indicators and their parameters.The end result of the evaluation of thewatershed carrying capacity was obtained by combining the value and the weight of each parameter [Peraturan Menteri Kehutanan Republik Indonesia Nomor : P.60/Menhut-II/2014,tentang Kriteria Penetapan Klasifikasi Daerah Aliran Sungai (in Indonesian)]

Bodri watershed carrying capacity

The evaluation of the watershed carrying capacity is considered Very Good when the score is <70; Good when the score is between >70 and <90; Moderate when the score is between >90 and <100; Poor when the score is between >100 and <130; and Very Poor when the score is >130 [Peraturan Pemerintah Nomor 37 Tahun 2012, Tentang Pengelolaan Daerah Aliran Sungai (in Indonesian);Peraturan Menteri Kehutanan Republik Indonesia Nomor : P. 60 /Menhut-II/2014, tentang Kriteria Penetapan Klasifikasi Daerah Aliran Sungai (in Indonesian)]. Whereas, the evaluation of the watershed classification according to carrying capacity consists of two classifications, i.e. maintained classification (carrying capacity <100; good-very good)

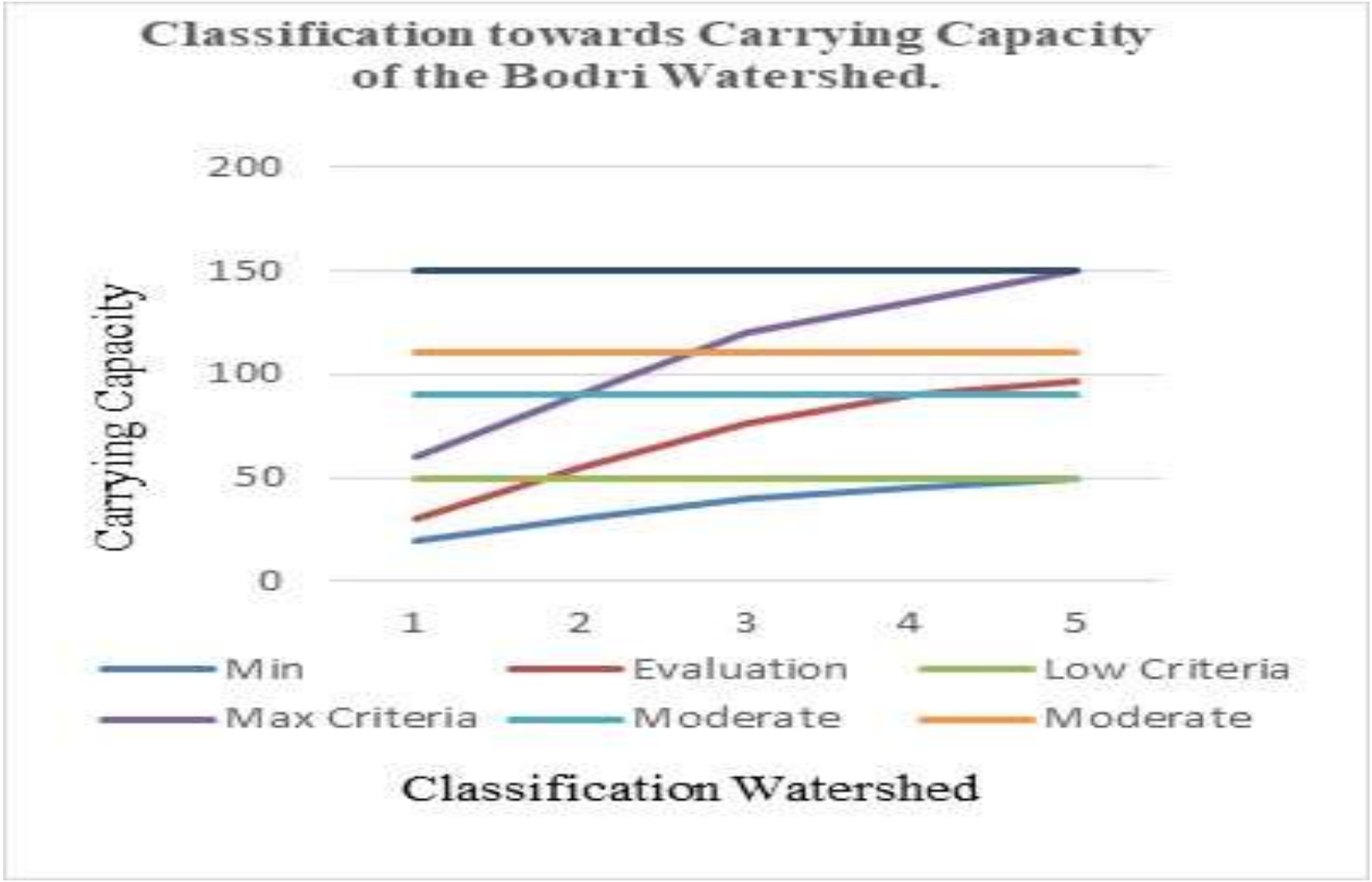
Bodri watershed carrying capacity

and restored classification (carrying capacity >100; poor-very poor) [Peraturan Pemerintah Nomor 37 Tahun 2012, Tentang Pengelolaan Daerah Aliran Sungai (in Indonesian)].

According to the data analysis the carrying capacity of Bodri Watershed was 96.7. In other words, the watershed was classified moderate and maintained. Therefore, it had not agreed with the existing condition. By increasing the carrying capacity into moderate (>90 t0 <110), the classification became improved. Therefore, the classification of the carrying capacity of Bodri Watershed was considered moderate and "to be improved" not "to be maintained" (fig.3).

Bodri watershed carrying capacity

Fig. 3. Classification towards Carrying Capacity of the Bodri Watershed.



Conclusions

Carrying capacity of Bodri Watershed was 96.7, consisting of as follows:

- land condition criteria (critical area, vegetation covering, and erosion index) with score of 10, respectively, making a total score of 30;
- water management (stream regime coefficient 7.5; annual stream coefficient 2.5; sediment content 6; floods 3, water use index 6), making a total score of 25;
- socio-economic condition (population stress 7.5, population welfare 10.5, law enforcement 3.75), making a total of 21.5;
- building investment (urban classification 6.25, building value 7.5), making a total score of 13.75;
- and area spatial use (conservation area 3.75, cultural area 2.5), making a total score of 6.25.

Conclusions

The evaluation of Bodri Watershed resulted in moderate carrying capacity and maintained classification. This evaluation did not apply to the existing condition. Using the moderate carrying capacity (>90 to <110), with improved classification, the Bodri Watershed classification was considered moderate, and "to be improved" not "to be maintained".


Thanks You