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ANALYSIS OF THE INFLUENCE OF ENVIRONMENTAL BEHAVIOR ON THE WATER BALANCE OF KALIGARANG WATERSHED, CENTRAL JAVA

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Abstract

The increasing population and land needs have led to changes in people's behavior towards the watershed, resulting in indications of disruption of the water balance. Therefore, it is necessary to investigate how community behavior affects the water balance of the Kaligarang watershed. This research is a combination of quantitative and qualitative approaches. The method of withdrawing respondents was purposive sampling. Data collection was done through observation, documentation, questionnaire distribution to respondents and interviews with key persons. Calculation of water balance using the Thorntwaite-Mather method. The results of the water balance calculation show that in periods 1 and 2 there was a surplus from December to April and a deficit from May to November. Deficits tend to increase while surpluses tend to decrease. From period 1 to period 2 the deficit increased by 142 mm and the surplus decreased by 316 mm. The tabulation results show that there are community behaviors that have a negative influence on water balance. This is reinforced by the results of interviews with key figures (key person) stating that environmental behavior has a negative influence on water balance.

***Keywords**: Aspects, Community Behavior, Environmental Behavior, Water Balance*

1. Introduction

The hydrological cycle broadly includes *inflow*, system structure and *outflow* factors. Inflow is the amount of water that enters a particular watershed through one or more processes that occur within the watershed. System structure is the workings of a watershed, such as watershed morphometry, soils, vegetation and land use. *Outflow* is an amount of output (water) whose size depends on the relationship between inputs and system structure. The *inflow* and *outflow* process can be formulated into a water balance formula or the so-called *water balance concept*. Water Balance of a watershed is when the amount of *inflow in the* form of rain and the amount of *outflow* in the form of runoff in that period is equal to zero. If there is an imbalance between the amount of input and the amount of output, it means that the workings and structure of the system in the watershed are disturbed.

Recently, there have been frequent complaints in several cities, especially on the island of Java, that there has been a drought in people's wells, a decrease in groundwater levels, on the contrary, in some places there are frequent floods during the rainy season. This is an indication of a disturbance in water balance. This change in water balance is allegedly due to the influence of community behavior. Similarly, in the city of Semarang, flooding has become a hot topic of discussion, not only among ordinary people, but also among experts, that there has been a change in land use that has caused a disturbance in the function of the watershed ecosystem. In addition, there has been disagreement about how much influence vegetation change as a result of land use change has on the reduction or increase of *water yield* at the site of activities that affect watershed characteristics such as: *peak flow, runoff volume, runoff* coefficient and others.

The Kaligarang watershed, whose estuary is located in the city of Semarang, has been disturbed. This is characterized by: 1) the runoff coefficient tends to increase from year to year, 2) the Q max / Q min ratio tends to increase, 3) the groundwater level fluctuates greatly. This is of course strongly influenced by changes in factors that affect the water balance of the Kaligarang watershed such as land use change. Research that has been conducted in relation to water balance is mostly from the physical aspect only, there is still a lack of research that relates to community behavior. In fact, land use change is largely determined by community behavior factors, which in turn can affect the watershed environment including water balance. Therefore, it is necessary to conduct research on: **"Analysis of The Influence of Environmental Behavior on Water Balance Kaligarang Watershed, Central Java".** This study aims: a) to determine the water balance in the Kaligarang watershed and the environmental behavior of the people of Semarang and surrounding areas on the water balance of the Kaligarang watershed b) to determine the relationship of environmental behavior of the people of Semarang to the water balance of the Kaligarang watershed.

2. Research Methods

This type of research focuses more on *descriptive research* to find out problems and to obtain information and data at the research location. The purpose of descriptive research is to make a systematic, factual and accurate description of the facts or properties of a particular population or area. In a broad sense, the term survey research is usually used. The objectives of survey research are to: 1) seek detailed factual information that characterizes existing symptoms, 2) identify problems or to obtain justification for ongoing conditions and practices, 3) make comparisons and evaluations, 4) find out what other people are doing in dealing with the same problem or situation, in order to learn from them for the benefit of planning and decision making for the future.

The approach method in this research is a combination of *quantitative* and *qualitative approaches*, namely qualitative analysis supported by quantitative data. This qualitative method allows researchers to approach primary data directly from the source, so as to develop analytical, conceptual and categorical components of the data itself (Chadwick, Howard and Stan, 1991). This method of research was conducted because the problems of the social and physical aspects of the watershed are complex and many things are not revealed through statistical data, so a qualitative approach is needed. To complement the results of this study, quantitative data obtained through the results of questionnaires distributed to respondents to determine community behavior to support qualitative analysis data. Quantitative analysis was also used in calculating the Kaligarang watershed water balance using the *Tornthwaite-Mather* Method. This step is intended as supporting data to analyze the influence of community behavior on the Kaligarang watershed balance.

The scope of this research discusses the behavior of Kaligarang watershed communities towards their land. In this case, it means behavior that can affect the hydrological function of their land and thus influence the *water balance* in the watershed. Furthermore, this behavior is called "environmental behavior". The aspects of environmental behavior studied in this research are: knowledge and attitude aspects. Aspects of knowledge and attitudes can be known by using questionnaires and *in-depth* interviews (*depth interview*) which results in tables or graphs supported by qualitative data. The water balance aspect is calculated based on: 1) average rainfall (P), 2) average air temperature (° C), 3) potential evapotranspiration (EP), 4) actual evapotranspiration (Ea), 5) accumulated potential water loss (APWL), 6) water storage (S) and additional water storage (Δ S), 7) runoff and 8) deficit and surplus. The results can be presented in the form of trend graphs of water storage deficit/surplus over several periods.

The scope of the area taken in this study is the boundaries of the area according to the definition of the Kaligarang Watershed (DAS) as an ecosystem. The definition of watershed according to Linslely (1949), is an area drained by a river or river system that is interconnected in such a way that streams originating in a particular area exit through one out let. The Kaligarang watershed community in question is the community living in the *catchment area of* *the* Kaligarang watershed, which is divided into three major parts, namely upstream, middle and downstream.

The sampling technique used in this research is purposive sampling. According to Hadi (1997) this sampling technique is used to achieve certain goals. Determination of subjects is based on certain characteristics or traits that are considered to have a close relationship with previously known population characteristics. This determination is based on information that precedes (previous knowledge). In this study, the division of areas was carried out based on the dominant land use change. Land use change can be done based on existing land use maps over time (time series).

3. Results And Discussion

The Kaligarang Watershed is located in Central Java Province, flowing from the hilly and mountainous south to the alluvial land of the north coast. The Kaligarang River divides the city of Semarang into two parts. Geographically, the Kaligarang watershed stretches from 110° 15' East to 110° 25' East and 6° 57' N-S to 7° 12' N-S.

The Kaligarang watershed covers several landforms as follows: upstream of the Kaligarang River (South) consists of quarter volcanic hills, slightly to the center consists of Pleistocene volcanic hills, hilly limestone deposits, and in the lower part (*down strem*) consists of alluvial land. In the context of hydrology, the upper and middle landscapes are sufficient catchment areas.

In general, the geomorphology of the study area is influenced by two main processes, namely denudational processes and volcanic processes. Denudational processes occur in sedimentary rocks located in the northern part of the study area, where the rocks consist of tuffaceous sandstone, conglomerate, volcanic breccia and tuff. Some denudational processes also occur in marine sedimentary layers consisting of alternating claystone, marl, sandstone, conglomerate and volcanic breccia. The area is undulating hills with some rather steep cliffs, partly the result of advanced erosion.

Soil types include three types: alluvial soils formed by river and lake deposits, flat topography in the North coast, regosol soils from limestone rocks, hilly topography in the central part of the watershed, and red to brass mediterranean soils and grumusol from basic and intermediate igneous rocks, hilly topography in the upper part of the watershed. While the soil texture in the study area consists of clay, loam, dusty clay and sandy clay. In relation to water balance soil texture will determine the magnitude of the value of WHC (*water holding capacity*).

The types of land use in the study area include: settlements, rice fields, mixed gardens, moorlands, plantations, pastures, forests and ponds. Land use in the form of settlements, rice fields and ponds are mostly located on alluvial plains. While land use in the form of moor and mixed gardens are mostly in the hilly areas of the middle of the watershed. In the upper part of the watershed, there is little forest. Settlements spread in the middle and downstream areas and began to decrease on steep slopes. The complete land use can be seen from Table 1.

Administratively included in the Kaligarang watershed are Semarang Regency, Semarang City and Kendal Regency. Semarang City includes West Semarang District, South Semarang District, Banyumanik District, Gunung Pati District, and Mijen District. Semarang Regency that is included in the Kaligarang watershed includes: Ungaran District, Ambarawa District, and Bergas District. While in Kendal Regency which is included in the Kaligarang watershed includes Boja District and Limbangan District.

Table 1. Land Use Change in 2000 and 2019

No.	**Land Use Type**	**Period 1**		**Period 2**	
		Area (Ha)	**% area**	**Area (Ha)**	**% area**
1	Pond	184	0.8	308.4	1.4
2	Sawah	6284	27.8	5297	23.4
3	Moor	3339	14.8	5150	22.8
4	Mixed Garden	5679	25.1	4554	20.1
5	Settlements	3264	14.4	3841	17.0
6	Forest	2319	10.3	1975	8.7
7	Plantation	1533	6.8	1476.8	6.6
		22602	100.0	22602	100.0

Source: Calculation From Secondary Data

Population distribution in the Kaligarang watershed is generally concentrated along the Solo-Semarang highway and district roads. There are two types of population distribution: clustered and spread-even. Clustered population distribution is found in the lower watershed in the east, namely in West Semarang Subdistrict, South Semarang Subdistrict extending to the middle and upper watersheds, namely in Ungaran Subdistrict, the rest spread evenly. Clustered population distribution tends to have greater potential for land pressure.

3.1. Kaligarang Watershed Water Balance

This water balance calculation is made for two different periods, namely period 1 for the period 2000 to 2013 and period 2 for the period 2001 to 2019. In calculating the water balance, the WHC (*Water Holding Capacity*) value is required to be used as a reference for the highest limit of moisture that can be achieved by the soil. WHC is determined by soil texture and land use. The results of *overlaying* soil texture maps and land use maps are then included in the

WHC determination table from Torntwaite-Mather based on soil conditions and plants or land cover (*provisional water holding capacity with different conditions of* soil and *vegetatition*. The results can be seen in the following table:

Table 2. WHC calculation for period 1 (2000-2013)

Land Use	area (%)	Texture	Available Water (mm/m)	Root Zone Length (m)	WHC (mm)
Pond	0.8	-	-	-	-
Sawah	5.3	See	300	0.6	9.54
Sawah	13.2	dusty clay	250	0.4	13.20
Sawah	6.3	dusty fidget	200	1.25	15.75
Sawah	3	sandy mud	150	0.5	2.25
Moor	8.6	See	300	0.67	17.29
Moor	0.6	dusty clay	250	1	1.50
Moor	5.1	dusty fidget	200	1.25	12.75
Moor	0.5	sandy mud	150	1	0.75
Mixed Garden	2.4	See	300	0.67	4.82
Mixed Garden	13.8	dusty clay	250	1	34.50
Mixed Garden	1.9	dusty bracelets	200	1.25	4.75
Mixed Garden	7	sandy mud	150	1	10.50
Settlements	2.8	See	300	1.17	9.83
Settlements	8.3	dusty clay	250	1.67	34.65
Settlements	2.3	dusty bracelets	200	1.5	6.90
Settlements	1	sandy mud	150	2	3.00
Forest	10.3	dusty fidget	200	2	41.20
Plantation	1.2	See	300	0.67	2.41
Plantation	0.8	dusty clay	250	1	2.00
Plantation	4.8	dusty fidget	200	2	19.20
Total	100				246.79

Source: Calculation Result

Table 3. WHC calculation for period 2 (2001-2019)

Land Use	area (%)	Texture	Water Available	Root Zone Length	WHC
Pond	1.4	-	-	-	-
Sawah	4.3	See	300	0.6	7.74
Sawah	12.6	dusty clay	250	0.4	12.60
Sawah	4.1	dusty fidget	200	1.25	10.25
Sawah	2.4	sandy mud	150	0.5	1.80
Moor	13.2	See	300	0.67	26.53
Moor	0.9	dusty clay	250	1	2.25
Moor	7.9	dusty fidget	200	1.25	19.75
Moor	0.8	sandy mud	150	1	1.20
Mixed Garden	1.9	See	300	0.67	3.86
Mixed Garden	11.1	dusty clay	250	1	27.63
Mixed Garden	1.5	dusty fidget	200	1.25	3.80
Mixed Garden	5.6	sandy mud	150	1	8.41
Settlements	3.5	See	300	1.17	12.29

Land Use	area (%)	Texture	Water Available	Root Zone Length	WHC
Settlements	9	dusty clay	250	1.67	37.58
Settlements	3	dusty fidget	200	1.5	9.00
Settlements	1.5	sandy mud	150	2	4.50
Forest	8.7	dusty fidget	200	2	34.80
Plantation	1.1	See	300	0.67	2.21
Plantation	0.7	dusty clay	250	1	1.75
Plantation	4.8	dusty fidget	200	2	19.20
Total	100				247.15

Source: Calculation Result

From the results of the calculation of water balance using the Thornthwaite-Mather method, it can be seen that in periods 1 and 2 there is still the same range of water surplus and deficit months. Surpluses range from December to April and water deficits occur from May to November. Meanwhile, the value/magnitude of deficits and surpluses has changed. Deficits tend to increase and surpluses tend to decrease. From period 1 to period 2 the deficit increased by 142 mm and the surplus decreased by 316 mm. The following is a graph of the deficit-surplus for periods 1 and 2

Table 4 Kaligarang Watershed Water Balance Period 1 (2000-2013)

	Jan	Feb	Mar	April	May	June	July	Agus	Sep	Oct	Nop	Des	Σ
T	26.1	26.5	27.1	27.7	27.8	27.5	27.1	27.2	27.6	28.3	27.7	26.9	327.5
P	582	456	342	276	156	94	86	48	102	149	233	409	2933
PE	127	121	147	159	165	157	151	154	155	177	157	140	1810
P-PE	+455	+335	+195	+117	-9	-63	-65	-106	-53	-28	+76	+269	1123
AP WL	0	0	0	0	-9	-72	-72	-135	-243	-295	-323	0	-1149
ST	247	247	247	247	238	184	142	92	75	67	142	247	2175
dST	0	0	0	0	-8	-54	-42	-50	-18	-8	+76	+104	0
AE	127	121	147	159	164	148	128	98	120	157	157	140	1666
D	0	0	0	0	0	9	22	57	35	20	0	0	143
S	455	335	195	117	0	0	0	0	0	0	0	165	1267
RO	268	302	248	183	91	46	23	11	6	3	1	82	1264

Source: Calculation Results Using The Thornthwaite-Mather Standard Method

Table 5 Kaligarang Watershed Water Balance Period 2 (2001-2019)

	Jan	Feb	Mar	April	May	June	July	Agus	Sep	Oct	Nop	Des	Σ
T	26.6	26.5	27.3	27.7	28.3	27.6	27.4	27.3	27.9	28.3	27.9	27.2	330
P	442	339	366	292	130	95	26	39	59	138	246	355	2527
PE	137	120	151	159	177	159	157	156	161	177	162	146	1862
P-PE	+305	+219	+215	+133	-47	-64	-131	-117	-102	-39	+84	+209	665
APW	0	0	0	0	-47	-111	-242	-359	-462	-501	0	0	-

L													1722
ST	247	247	247	247	205	158	93	58	38	33	117	247	1937
dST	0	0	0	0	-43	-47	-65	-35	-20	-6	+84	+130	-2
AE	137	120	151	159	173	142	91	74	79	144	162	146	1578
D	0	0	0	0	4	17	66	82	83	33	0	0	285
S	305	219	215	133	0	0	0	0	0	0	0	79	951
RO	172	195	205	169	85	42	21	11	5	3	1	40	949

Source: Calculation Results Using The Thornthwaite-Mather Standard Method, 1957

Description:
T = Monthly average air temperature
(°C) at an altitude of 510 m a.s.l.
P = Monthly average rainfall
P-PE = Rain minus Evapotranspiration
APWL = Accumulated potential water loss
(Accumulated Potential Water Loss)
ST= Stored soil moisture
(Soli Moisture Storage)

AE= Actual evapotranspiration
dST= Change in soil moisture
(Change in Soil Moisture)
PE= Monthly evapotranspiration
RO= Monthly runoff (Thornthwaite-Mather)
Monthly average runoff = 50% of availability water for runoff
Water holding capacity (WHC) = 246.79
All units in mm

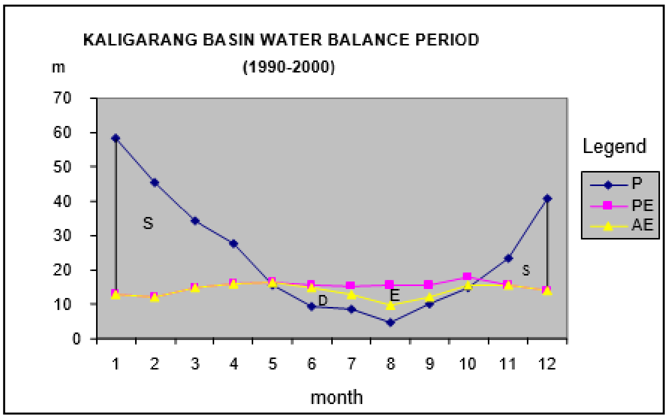

Figure 1 Kaligarang Basin Water Balance Periode 1
Source: Calculation Result

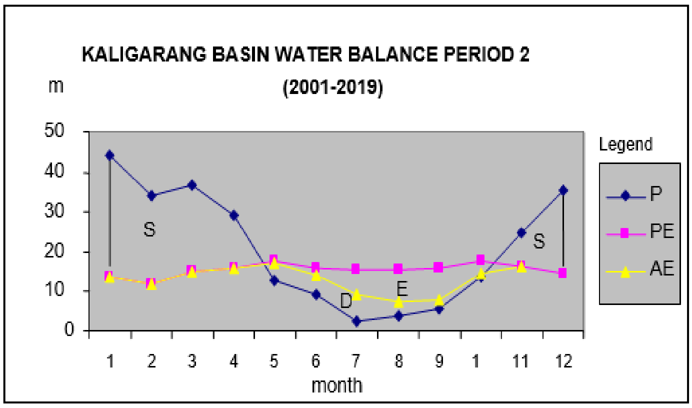

Figure 2 Kaligarang Basin Water Balance Periode 2

Source: Calculation Result

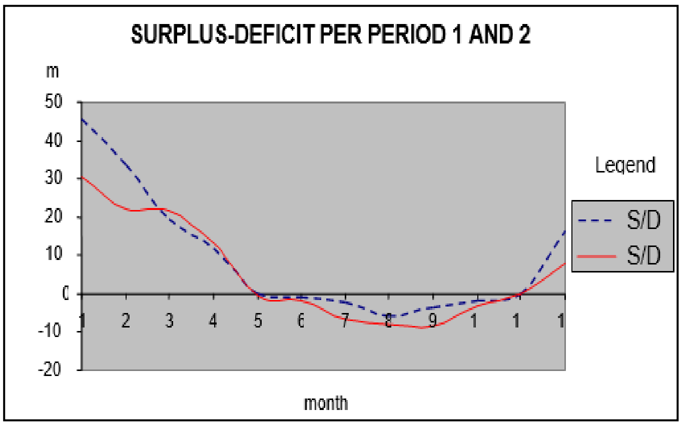

Figure 3 Kaligarang Basin Water Balance Periode 1and 2
Source: Calculation Result

3.2. Environmental Behavior on Kaligarang Watershed Water Balance

The following is the environmental behavior of the Kaligarang watershed based on behavioral components that include aspects of knowledge, attitudes and actions.

a) Knowledge/Perception

The aspect of community knowledge in the central part of the watershed averaged 3.00 (good), which means that the community understands, followed by the upstream and downstream watersheds with an average of 2.72 (medium) and 2.49 (medium) respectively, which means that in general the community has sufficient knowledge about aspects that affect the water balance in a watershed. However, there are still some things that fall into the bad category as follows: In the downstream watershed, there are several aspects that fall into the poor category, namely aspects of knowledge about the definition of the watershed (2.05), water balance (2.20), groundwater suppliers (1.90), river conditions (2.11), and understanding of forests and drought (2.00). Meanwhile, in the middle section, knowledge of drought and forest functions (2.15) fell into the poor category, and in the upstream section, knowledge of infiltration functions fell into the very poor category (1.53).

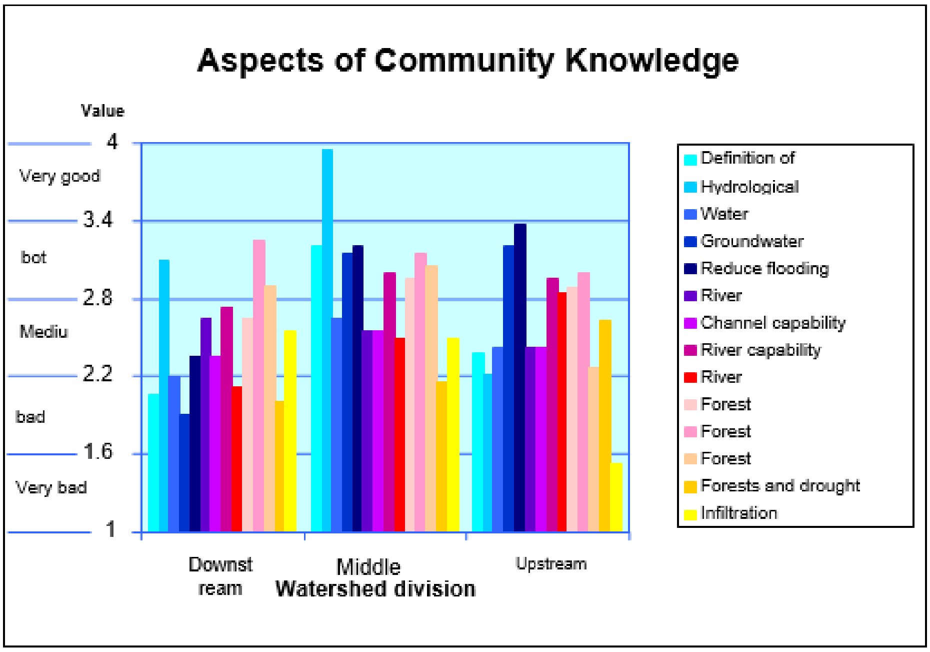

Figure 4 Aspects Of Community Knowledge

Source: Primary Data Calculation Results

b) Attitude

Behavior in the form of attitude is a product of the socialization process where a person reacts according to the stimuli he receives. Attitude leads to a certain object which means that self-adjustment to the object is influenced by the social environment and the willingness to react from the person to the object.

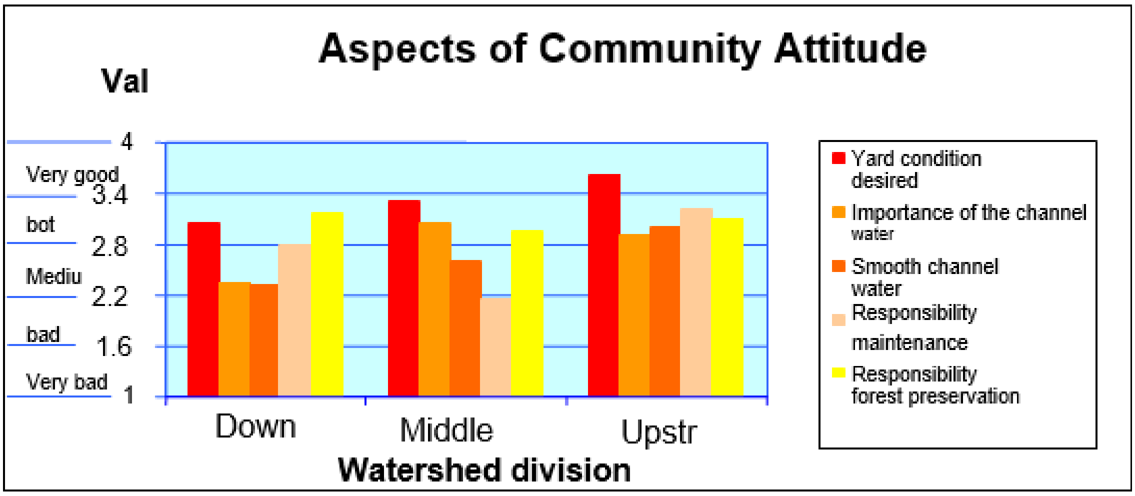

Figure 5 Aspects Of Community Attitute

Source: Primary Data Calculation Results

The average community attitude towards yards, drainage channels, rivers and forests is quite good with a value in the upstream area of 3.17 (good) followed by the middle area averaging 2.81 (good) and finally downstream averaging 2.73 (moderate). In the middle part of the watershed, there is an aspect of attitude that falls into the poor category, namely the aspect of responsibility for the maintenance of river bodies with a value of 2.15 (poor).

c) Action

The environmental behavior of the Kaligarang watershed community differs by area, with the upstream area exhibiting positive actions, the intermediate area exhibiting medium actions, and the downstream area exhibiting negative actions (Pont et al., 2005). In the center, features such as yard plant selection and waste removal from river bodies are rated as inadequate. On the other hand, the downstream area displays inadequate community behaviors in terms of land cover, yard plants, and channel cleanliness, which do not comply with water resource conservation guidelines (Pont et al., 2005).

Forest cover is widely accepted as a reliable measure of environmental integrity and biodiversity condition on a local and global scale (Porter-Bolland et al., 2012). Land cover is critical to environmental planning and management, and current information on land surface status is required (Wondie et al., 2011). Land use and land cover changes can impact soil erosion intensity (Özşahin et al., 2018; Sentian et al., 2022). The dynamics of land cover in conservation areas are critical for understanding how organisms interact with their surroundings (Ardiaristo et al., 2022).

To protect human health from harmful chemicals, environmental policymakers are increasingly relying on rigorous, quantitative risk assessments (Russell & Gruber, 1987). Spatial study of pollution sources and watershed hydrology is critical for assessing environmental risk and allocating resources to address nonpoint source pollution (Phillips, 1988). The fluctuation of future total precipitation in locations with different land cover types causes varied degrees of potential soil erosion risk (Sentian et al., 2022).

Overall, land cover, forest maintenance, soil erosion dynamics, and risk assessment methodologies all have an impact on watershed populations' environmental behavior. Understanding these processes is critical for successful environmental planning, conservation, and sustainable resource management.

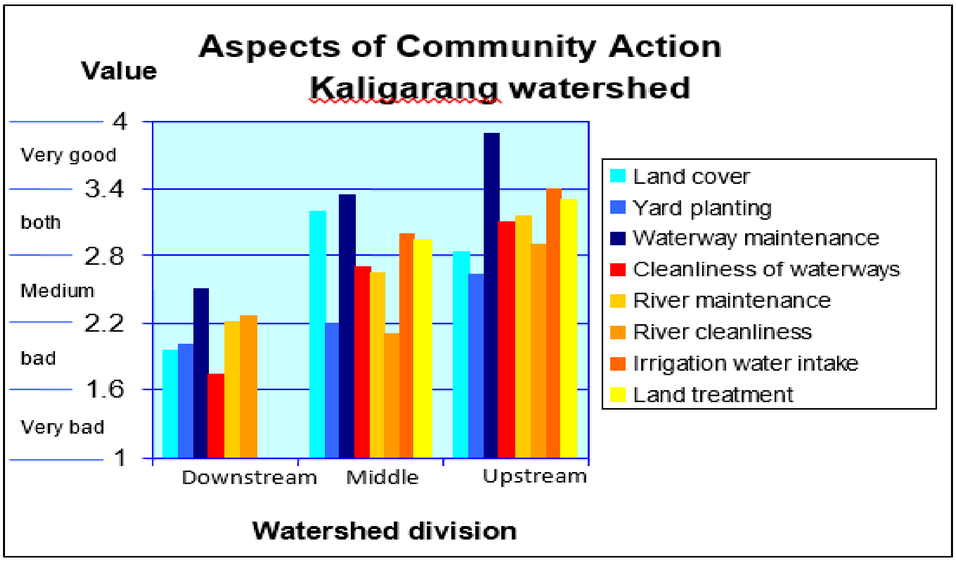

Figure 6 Aspects of Community Action Kaligarang Watershed

Source: Calculation Result

4. Conclusions

The results of the calculation of water balance using the Thornthwaite-Mather method show that the deficit tends to increase by 142 mm and the surplus tends to decrease by 316 mm. This shows that the water balance has an indication of disturbance. On the other hand, the results show that many people's behavior still has a negative influence on water balance. Therefore, it is necessary to strengthen the factors that influence changes in environmental behavior, through *compliance*, *identification* or *internalization of* benefits.

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