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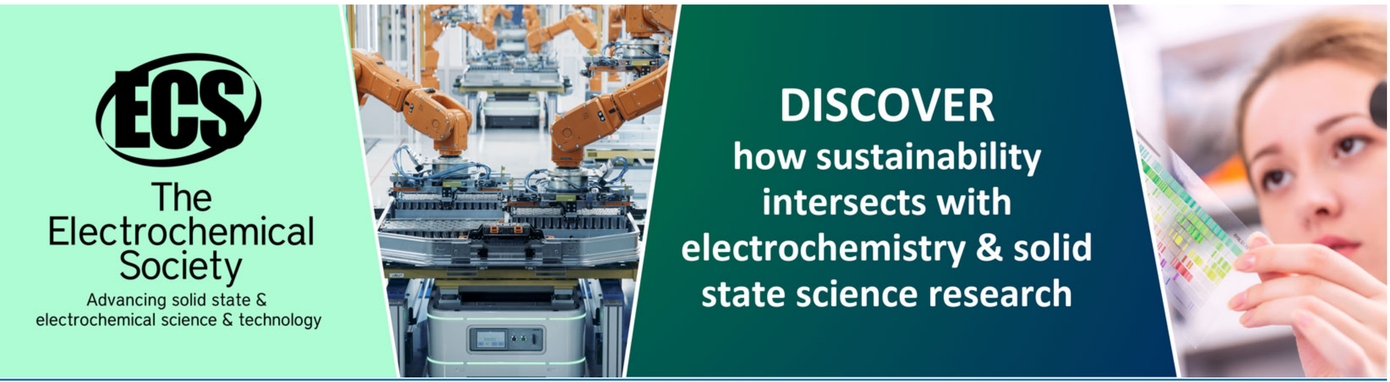
To cite this article: L M Rachman *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **622** 012023







IOP Conf. Series: Earth and Environmental Science **622** (2021) 012023 doi:10.1088/1755-1315/622/1/012023

# Application of SWAT in selecting soil and water conservation techniques for preparing management recommendation of Cilemer watershed, Banten, Indonesia

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**Abstract.** The quality of watershed ought to be maintained because of its function as a life buffer of living things, especially in water and other material needs provision. From the indication result, Cilemer watershed was degraded, therefore, it demanded planning efforts to restore watershed quality. This study aimed to determine watershed management directives and selecting some alternatives of soil and water conservation techniques by using Soil Water Analysis Technique (SWAT) method. Six scenarios were applied, there were: strip cropping (Scenario 1), agroforestry (Scenario 2), reservoir or small reservoir (Scenario 3), strip cropping and agroforestry combination (Scenario 4), strip cropping and reservoir combination (Scenario 5), and strip cropping, agroforestry, and reservoir combination (Scenario 6). The result showed Scenario 6 was the most effective to maintain watershed quality. Compared to the existing conditions, Scenario 6 could decrease Qmax-Qmin ratio by 34.57%, decreased the surface flow by 33.64%, so, the runoff coefficient decreased from 0.25 to 0.16. Moreover, Scenario 6 also increased the base flow by 52.16% (from 357.55 mm to 544.07 mm), water yield by 4.16% (from 904.55 mm to 943.68 mm). However, Scenario 2 was the most optimal scenario since its input was lighter and involving a smaller restored area.

## 1. Introduction

Watershed quality in many cases is being a consideration and using in regional planning. The quality of watershed is very decisive to determine the productivity, environmental quality and pollution and the role of environment services in a region [1]. Watershed is a unity land area with the river and its tributaries functioning as a reservoir, storage and a place to drain rainwater into the lake and the sea naturally which is bordered by a topographic separator and to the sea waters area which is still affected by land activities [2]. According to Rahayu [3], the function of watershed can be described as a landscape condition that affects the quality, the quantity, and the time period of a river flow or groundwater. In detail it includes: 1) transmission or river flow process, 2) buffering ability 3) the gradual release of water from rainfall which is stored in the soil, 4) water quality, and 5) maintaining the soil reliability in the watershed. Integrated watershed management is basically the development of congenial objectives between various natural resource management systems. This can be done through utilizing, organizing, maintaining, supervising, controlling, restoring and developing watersheds efforts based on the preservation of a congenial and balanced environmental capacity to support sustainable development to improve human welfare [4]. Watershed management is based on the resource sustainability principle that brings together the interests of productivity and resource conservation to achieve several goals. To maintain watershed sustainability, it is necessary to maintain the balance of the ecosystem by safeguarding reciprocal relations between the watersheds components run well to get optimal results.

The Cilemer Watershed is a watershed in Banten Province and its condition was getting worse. Population growth and the decrease of forest area due to forest conversion to agricultural land and conversion of agricultural land to residential land were suspected to be the main causes. Some indicators indicate the decreased quality of the Cilemer watershed, i.e., the increasing of the frequency and widespread of the flood, drought problems during the dry season, increasing annual flow coefficient (AFC) and/or river regime coefficient (RRC), decreasing water yield and water supply for irrigation.

Efforts are required to improve the conditions and quality of the Cilemer Watershed through various soil and water conservation techniques. Soil conservation is the use of a set of land in accordance with its capabilities and applying any measures needed to prevent soil or land degradation. Whereas water conservation is an effort to preserve water in the soil, to enter, save, and hold water into the soil when the rain comes or rain season, then the water could be released and used during the dry season [5]. Soil and water conservation to improve watershed quality include into vegetative, chemistry, and mechanical or civil engineering methods [6]. A reservoir can be useful to reduce the surface flow, to increase the water retention, to collect and to store water. These can be used to increase the water supply for agriculture, to increase water entering into the soil (infiltration), which finally improves the watershed quality, especially that is indicated by it's River Regime Coefficient (RRC) or Annual Flow Coefficient (AFC) of a watershed [7]. According to Kustamar [8], a combination of soil and water conservation using vegetative, chemical and mechanical methods effectively improves the quality of watersheds.

According to [9], the SWAT (Soil and Water Assessment Tool) model can be used to predict watershed hydrological conditions based on land use changes, the application of soil and water conservation techniques and the global climate change circumstance. This research aimed to formulate Cilemer Watershed Management Directives by choosing alternative soil and water conservation technique using Soil Water Analysis Technique (SWAT) method.

## 2. Material and methodology

### *2.1. Time and location*

The research was carried out from January to August 2017 in the Cilemer Watershed Area, which has about 28019.94 ha area and administratively is included in Lebak District and Pandeglang District, Banten Province.

### *2.2. Material and tool*

The fundamental materials used in this study are secondary data. They especially consist of Cilemer daily river flow discharge data from 2010 to 2015; climate data for the period of 2010-2015, maximum and minimum air temperatures, wind speed, humidity and solar radiation; Map of Land Cover Scale 1: 250000 from the Forest Planology Agency (BAPLAN); Land Map Scale 1: 250000 from the Large Center for Research and Development of Land Resources (BBPPSL); and the Digital Elevation Model (DEM) map with a resolution of 30 meters from CGIAR-CSI. While, the main tools are: 1) a set of computer with ArcGIS 10.1 software and ArcSWAT 10.1.18 version as an interface, pcpSTAT, SWAT Plot, SWAT BFlow, and SWAT CUP; Microsoft Office 2010; Global Positioning System (GPS); ring sampler; 5) double-ring infiltrometer; and equipment to analyze the soil physical properties in the laboratory related to this research.

### *2.3. Research methodology*

Some methods used in this research are presented in Table 1.

**Table 1** The methods used for various aspects/factors

| Aspect/Factors | Method | Information/Formula |
|---|---|---|
| Secondary Data | Data collection through several related institutions | Especially from the Public Works and Public Housing Agencies (PUPR) Banten Province, Balai PSDA Ciliman-Ciwasarna River Region, |

| Aspect/Factors | Method | Information/Formula |
|---|---|---|
| | | Planology Agency of Ministry of Environment and Forestry, BBPPSL, BMKG Class I Serang, CGIAR-CSI. |
| Soil Sampling and Analysis | - Infiltration rate (double-ring infiltrometer method)<br>- Soil permeability (constant head method)<br>- Soil bulk density (gravimetric method)<br>- Available water (pressure plate and membrane apparatus method)<br>- Organic carbon (Walkey and Black method)<br>- Soil texture (pipette method) | - Field soil observation was carried out to identify the depth of the effective soil depth, rock and/or stone composition (%) on the soil surface and to measure the infiltration rate.<br>- Soil sampling then is analyzed in the laboratory for determining the soil bulk density, soil texture, soil permeability, organic carbon content, and available water. |
| Rainfall Analysis | The average rainfall (P) was calculated using Thiessen method | $P = \frac{(A_1 x P_1) + (A_2 x P_2) + \ldots\ldots + (A_n x P_n)}{\sum A}$<br>$A_n$ = area of each polygon<br>$P_n$ = rainfall of each station |
| Runoff (RO) Analysis of River Flow | RO is stated in the thickness unit (mm) | $RO = \frac{\text{Discharge } (m^3/s) * \sum \text{days} * 86400 \text{ s}}{\text{DAS area } (m^2)}$ |
| Watershed Condition/Quality Analysis | - Flow Coefficient (C) | - C = total runoff (mm)/total rainfall (mm)<br>- $C \leq 0.2$ very low<br>$0.2 < C \leq 0.3$ low<br>$0.3 < C \leq 0.4$ medium<br>$0.4 < C \leq 0.5$ high<br>$C > 0.5$ very high |
| | - River Regime Coefficient (RRC) = ratio of maximum discharge ($Q_{max}$) and minimum discharge ($Q_{min}$) | - RRC = $Q_{max}/Q_{min}$<br>- score RRC $\leq 20$ very low;<br>$20 \leq RRC \leq 50$ low;<br>$50 \leq RRC \leq 80$ medium;<br>$80 \leq RRC \leq 110$ high;<br>dan RRC $\geq 110$ very high |
| | - Water yield<br>- Water Use Index (WUI)<br>- Water Supply (WS)<br>- Water Requirement (WR) = Qtot | - WUI = water demand ($m^3$)/water supply ($m^3$)<br>- WS = Q x d x 86400<br>- $Q_{tot} = Q_p + Q_d + Q_t + Q_i + Q_s$<br>- $Q_p$ = water requirements for agriculture<br>- $Q_d$ = domestic water needs<br>- $Q_t$ = water needs for animal husbandry<br>- $Q_i$ = water needs for industry<br>- $Q_s$ = river flushing water needs |
| SWAT Model Development | Procession Series: Data preparation, watershed delineation, HRU analysis, climate data input, building data input, and testing the "run" SWAT model that has been built | Watershed Delineation using DEM Map |

| Aspect/Factors | Method | Information/Formula |
|---|---|---|
| SWAT Model Calibration | Determinant coefficient model ($R^2$) and NSE efficiency model | For $R^2$, if score $R^2 \geq 0.5$ can be accepted<br>For NSE Clarification Score*:<br>score NSE $\leq 0.5$ not satisfactory;<br>$0.50 \leq$ NSE $\leq 0.65$ satisfying;<br>$0.65 \leq$ NSE $\leq 0.75$ good, and<br>$0.75 \leq$ NSE $\leq 1.00$ very good |
| SWAT Model Validation | Determinant coefficient model ($R^2$) and NSE efficiency model | For $R^2$, score $R^2 \geq 0.5$ can be accepted<br>For NSE Clarification Score*:<br>score NSE $\leq 0.5$ not satisfactory;<br>$0.50 \leq$ NSE $\leq 0.65$ satisfying;<br>$0.65 \leq$ NSE $\leq 0.75$ good, and<br>$0.75 \leq$ NSE $\leq 1.00$ very good |

NSE = Nash-Sutcliffe Efficiency (Moriasi, et.al., 2007 in the [10])

### *2.4. The use of scenario*

For the simulation to choose the best alternative for Cilemer Watershed Area improvement, 6 (six) scenarios were chosen. The description from six scenarios along with their area is presented in Table 2.

**Table 2** Projected land management types and soil and water conservation techniques from the six scenarios along with simulated hydrological parameters and extent of the improvement

| Scenario | Soil and Water Conservation Techniques | Simulated Hydrological Parameters | Simulation Location | Area | |
|---|---|---|---|---|---|
| | | | | Ha | % |
| Scenario 1 | Strip cropping | STRIP_CN[a], STRIP_C[b], STRIP_N[c], STRIP_P[d] | 1, 2, 5-24 | 13852 | 49.44 |
| Scenario 2 | Agroforestry | CN2, SOL_C, SOL_K, SOL_BD, SOL_AWC | 1, 2, 5-10, 12-18, 20-24 | 1999 | 7.14 |
| Scenario 3 | Small reservoir or "embung" | PND_SA, PND_VOL, CN2 | 1, 2, 6-10, 12-24 | 10913 | 38.95 |
| Scenario 4 | A combination of strip cropping and agroforestry | STRIP_CN,STRIP_C, STRIP_N, STRIP_P CN2, SOL_C, SOL_K, SOL_BD, SOL_AWC | 1, 2, 5-24 | 13852 | 49.44 |
| Scenario 5 | A combination of strip cropping and small reservoir | STRIP_CN, STRIP_C, STRIP_N, STRIP_P PND_SA,PND_VOL,CN2 | 1, 2, 5-24 | 13852 | 49.44 |
| Scenario 6 | A combination of strip cropping, agroforestry and small reservoir | STRIP_CN, STRIP_C, STRIP_N, STRIP_P CN2, SOL_C, SOL_K, SOL_BD, SOL_AWC PND_SA,PND_VOL, CN2 | 1, 2, 5-24 | 12912 | 46.08 |

[a]Surface flow curve numbers for cropping strips based on USDA-NRCS, 2004 and William, et.al., 1990 in [11].
[b]USLE C Factors based on [12]
[c]Manning's roughness coefficient based on Engman, 1983, in [13].
[d]The USLE P factor for strip cropping based on Wischmeir and Smith, 1978 in [14].

### *2.5. Setting and calculating scenario scores*

After calculating the scores for each scenario, then scoring based on classification of percent change. The score is presented in Table 3.

**Table 3** Score setting for every present change range class

| Change range | < 20% | 20%-40% | 40%-60% | 60%-80% | > 80% |
|---|---|---|---|---|---|
| Score | 1 | 2 | 3 | 4 | 5 |

## 3. Result and discussion

### *3.1. Land use*

Land use with the largest area is the Dryland Mixed Farming (13778 ha or 49.18% of total area). It then followed by plantations (5582 ha or 19.93%), rice fields (2689 or 9.60%), industrial forest (2072 ha or 7.40%), secondary dryland forests (1824 ha or 6.51%), settlements (1039 ha or 3.71%), dryland farming (872 ha or 3.12%) and shrubs (159 ha or 0.57%).

**Table 4** Area and percentage of Cilemer watershed land use distribution in the 2013

| No | Land Use | Area | |
|---|---|---|---|
| | | (ha) | % |
| 1 | Secondary Dryland Forest | 1824 | 6.51 |
| 2 | Industrial Forest | 2072 | 7.40 |
| 3 | Dryland Farming | 872 | 3.12 |
| 4 | Dryland Mixed Farm | 13778 | 49.18 |
| 5 | Plantation Estate | 5582 | 19.93 |
| 6 | Shrubs | 159 | 0.57 |
| 7 | Rice Fields | 2689 | 9.60 |
| 8 | Settlement | 1039 | 3.71 |
| | Total | 28019 | 100 |

Source: Planology Agency of Ministry of Environment and Forestry (Badan Planologi Kementerian Lingkungan Hidup)

The decrease in forest area and the land use which not employing soil and water conservation techniques will decline soil capacity in absorbing water and increase surfaced flow, erosion, and sediment discharge [14;15]. The mixed upland farming and dryland agriculture are suspected land uses to be the cause of the deteriorating condition of the Cilemer Watershed recently. In addition, the reduction of secondary dryland forest area and the extend of dryland agriculture and settlement will impend the quality of the Cilemer watershed and become worse (Table 4).

### *3.2. Water supply, water demand and water use index*

Water supply or availability in the Cilemer watershed has greatly decreased from 2011 to 2015. The decreased of water supply from 2011 to 2012 reached 23.50%, from 2011 to 2013 reached 20.68%, from 2011 to 2014 reached 31.85% and the worst was from 2011 to 2015, until sustained a decrease from 453768248 $m^3$ in 2011 to 253041782 $m^3$ in 2011 or decreased by 44.24% (Table 5).

**Table 5** Water supply changes and fluctuations from 2011 to 2015

| Month | Water Supply ($m^3$) | | | | |
|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 |
| January | 60048000 | 96733440 | 110410500 | 63996480 | 54916128 |
| February | 39648960 | 50051520 | 39744000 | 22213440 | 41395200 |
| March | 135639360 | 67046400 | 22239360 | 21660480 | 45916704 |
| April | 85803840 | 36054720 | 45437760 | 34387200 | 10162428 |
| May | 44928000 | 13400640 | 25030080 | 12052800 | 31060512 |
| June | 11007360 | 5590080 | 22567680 | 10065600 | 12414786 |
| July | 16113600 | 3248640 | 26948160 | 8268480 | 4214016 |
| August | 2048516 | 1086968 | 13361342 | 11103794 | 1546560 |

| Month | Water Supply ($m^3$) | | | | |
|---|---|---|---|---|---|
| | 2011 | 2012 | 2013 | 2014 | 2015 |
| September | 2285568 | 392832 | 8347680 | 8499456 | 1745578 |
| October | 7516800 | 2909729 | 4841187 | 23838039 | 4570560 |
| November | 20659392 | 27614304 | 19061280 | 41086656 | 10824430 |
| December | 28068852 | 43002116 | 21923303 | 52057394 | 34274880 |
| Total | 453768248 | 347131389 | 359912392 | 309229818 | 253041782 |
| Changes ($m^3$) | | 106636859* | 93855856* | 144538430* | 200726466* |
| Changes (%) | | -23.50* | -20.68* | -31.85* | -44.24* |

Note: * towards 2011

As a whole, water demand for various aspects in the Cilemer watershed from 2011 to 2015 had a slight increase, from 212076335 $m^3$ in 2011 to 213520836 $m^3$ in 2015 or an increase of 1.41 during the period (Table 6).

**Table 6** Water demand changes and fluctuations from 2011 to 2015

| Year | Water Demand ($m^3$/tahun) | | | | | Total | Δ (%) |
|---|---|---|---|---|---|---|---|
| | Domestic | Agriculture | Animal Husbandry | Industry | Flushing | | |
| 2011 | 142939026 | 17797131 | 969830 | 1832717 | 48537630 | 212076335 | |
| 2012 | 143424163 | 18060820 | 989455 | 1850159 | 49256782 | 213581380 | 0.71 |
| 2013 | 143358435 | 18110857 | 915624 | 1868148 | 49393246 | 213646311 | 0.74 |
| 2014 | 142841999 | 18128145 | 927470 | 1872215 | 49440395 | 213210225 | 0.53 |
| 2015 | 143810036 | 18387303 | 869122 | 1876283 | 50147189 | 215089933 | 1.41 |
| Average | 143274732 | 18096851 | 934300 | 1859904 | 49355049 | 213520836 | |

Even though it is still a surplus or not having a deficit of water, WUI has increased quite sharply over the five years from 2011 to 2015. In 2011 the WUI was only in the position of 0.47 and had become 0.85 in 2015 (Table 7).

**Table 7** Water Use Index (WUI) changes and fluctuations and its category from 2011 to 2015

| Year | Water Supply ($m^3$) | Water Demand ($m^3$) | Water Use Index | Category |
|---|---|---|---|---|
| 2011 | 453768248 | 212076335 | 0.47 | Low |
| 2012 | 347131389 | 213581380 | 0.62 | Moderate |
| 2013 | 359912392 | 213646311 | 0.59 | Moderate |
| 2014 | 309229818 | 213210225 | 0.69 | Moderate |
| 2015 | 253041782 | 215089933 | 0.85 | High |

The increase in water demand is suspected to be caused by the population increasing. Otherwise, the decrease of water supply is caused by the worsening conditions and quality of the Cilemer Watershed. The increase of WUI in the Cilemer Watershed is from 0.47 in 2011 and becomes 0.85 in 2015 needs attentive concern. Although WUI < 1.0 is still signified surplus condition, the increase in WUI is suspected due to a decrease in the water supply or availability due to degenerate of the Cilemer Watershed quality. Various efforts to improve the Cilemer Watershed quality are immediately needed to keep the water supply still remains greater than water demand.

### *3.3. Scenario simulation results*

After calibration, the value of $R^2$ becomes 0.63 and NSE becomes 0.62 (satisfactory). While, validation produces the score of $R^2$ = 0.57 and NSE = 0.52 (satisfactory). Thus, the built SWAT model is ready or feasible to be used for scenario simulation process. The existing condition of the Cilemer Watershed is already unhealthy or bad. Some watershed quality indicators that had shown these conditions are the value of RRC or $Q_{max}/Q_{min}$ ratio of 119.7 which is classified as very high (see Table 8). All the results shown by the six scenarios in recovering the Cilemer Watershed quality can be seen in Table 8 and Table 9.

**Table 8** Simulation results towards maximum river discharge, minimum river discharge and RRC

| Scenario | Average Discharge | | $Q_{max}$ | | $Q_{min}$ | | RRC = $Q_{max}/Q_{min}$ | | RRC Clarification | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $m^3$/sec | Δ (%) | $m^3$/sec | Δ (%) | $m^3$/sec | Δ (%) | Score | Δ (%) | | Δ |
| Existing | 8.41 | | 41.08 | | 0.34 | | 119.7 | | VB | |
| Scenario 1 | 8.61 | 2.38 | 39.20 | -4.58 | 0.42 | 23.53 | 92.9 | -22.4 | B | 1 class (VB→ B) |
| Scenario 2 | 8.49 | 0.95 | 39.59 | -3.63 | 0.37 | 8.82 | 107.0 | -10.6 | B | 1 class (VB→ B) |
| Scenario 3 | 8,68 | 3.21 | 39.15 | -4.70 | 0.42 | 23.53 | 94.3 | -21.2 | B | 1 class (VB→ B) |
| Scenario 4 | 8.56 | 1.78 | 37.93 | -7.67 | 0.41 | 20.59 | 92.2 | -23.0 | B | 1 class (VB→ B) |
| Scenario 5 | 8.68 | 3.21 | 34.04 | -17.14 | 0.43 | 26.47 | 78.8 | -34.2 | M | 2 class (VB→ M) |
| Scenario 6 | 8.70 | 3.45 | 34.38 | -16.31 | 0.44 | 29.41 | 78.3 | -34.6 | M | 2 class (VB→ M) |

VB = Very Bad; B = Bad; M = Moderate

From Table 8, it is shown that the Scenario 6 produced the best indication improvement on watershed quality which was indicated by the lowest $Q_{max}/Q_{min}$ ratio or RRC (78.3), then followed by the Scenario 5 (78.8), where both are still classified as moderate. While the Scenario 2 gave the smallest recovery. However, no one of the six scenarios was able to produce a RRC ratio lower than 20 to achieve an indicator for very good category watershed quality.

**Table 9** Simulation results on surface flow, flow coefficient and water yield

| Scenario | Rainfall | Surface Flow | | Basic Flow | | AFC | | AFC Classification | | *Water Yield* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (mm) | mm | Δ (%) | Score | Δ (%) | (tons/day) | Δ (%) | | | mm | Δ (%) |
| Existing | 1972.6 | 486.0 | | 357.5 | | 0.25 | | G | | 904.5 | |
| Scenario 1 | 1972.6 | 345.4 | -28.9 | 502.6 | +40.6 | 0.18 | -28.0 | VG | 1 class (G→ VG) | 923.2 | +2.1 |
| Scenario 2 | 1972.6 | 442.9 | -8.9 | 404.5 | +13.1 | 0.22 | -12.0 | G | Unchanging | 912.8 | +0.9 |
| Scenario 3 | 1972.6 | 343.9 | -29.2 | 522.1 | +46.0 | 0.17 | -32.0 | VG | 1 class (G→ VG) | 941.1 | +4.0 |
| Scenario 4 | 1972.6 | 363.8 | -25.1 | 480.2 | +34.3 | 0.18 | -28.0 | VG | 1 class (G→ VG) | 917.5 | +1.4 |
| Scenario 5 | 1972.6 | 335.5 | -31.0 | 529.5 | +48.1 | 0.17 | -32.0 | VG | 1 class (G→ VG) | 940.7 | +3.9 |
| Scenario 6 | 1972.6 | 322.5 | -33.6 | 544.1 | +52.2 | 0.16 | -36.0 | VG | 1 class (G→ VG) | 943.7 | +4.2 |

Note: G = Good VG = Very Good

For AFC, the Scenario 6 also produced the best indication in improving watershed quality. It was able to reduce AFC from 0.25 to become 0.16, followed by the Scenario 5 and 3, which both produced the AFC value of 0.17 (see Table 9). Similar with its effect on RRC, the Scenario 2 also produced the smallest recovery that was indicated by the highest score of AFC as compared to the other scenarios.

Finally, the score calculation was done to find out the effects of various efforts to improve the watershed quality through the six scenarios as a whole or in the aggregate. The score is presented in Table 10.

**Table 10** The score of each scenario effects on the improvement of the Cilemer watershed quality parameters

| Scenario | AFC | | RRC | | Water Yield | | Total | Rank |
|---|---|---|---|---|---|---|---|---|
| | Δ (%) | Score | Δ (%) | Score | Δ (%) | Score | Score | |
| Existing | | | | | | | | |
| Scenario 1 | -28.0 | +2 | -22.4 | +2 | +2.1 | +1 | +5 | 5 |
| Scenario 2 | -12.0 | +1 | -10.6 | +1 | +0.9 | +1 | +3 | 6 |
| Scenario 3 | -32.0 | +2 | -21.2 | +2 | +4.0 | +1 | +5 | 3 |
| Scenario 4 | -28.0 | +2 | -23.0 | +2 | +1.4 | +1 | +5 | 4 |
| Scenario 5 | -32.0 | +2 | -34.2 | +2 | +3.9 | +1 | +5 | 2 |
| Scenario 6 | -36.0 | +2 | -34.6 | +2 | +4.2 | +1 | +5 | 1 |

Scenario 1 (strip cropping with a stripe width of 20-50 cm with a cover crop that will be applied to an area of 13852 ha) would be able to reduce AFC by 28.1%, maximum discharge 4.58% and RRC 22.4% and to increase the discharge average 2.38%, minimum discharge 0.95% and water yield 2.1%, so it got ranked 5$^{th}$ out of the six scenarios. Scenario 2 (agroforestry that will introduce Sengon trees for mixed gardens in an area of 1999 ha), through the lowest inputs and smallest improvement area, got the lowest-ranked (6$^{th}$ rank) and it only would be able to reducing AFC by 12.0%, maximum discharge of 3.63%, and RRC 10.6% and to increase the average discharge of 0.95%, minimum discharge of 8.82 % and 0.9% water yield. Scenario 3 used civil technic by reservoir method with dimensions of about 100 $m^2$ per ha, with a depth of 3 m could contain water with a volume of about 300 $m^3$ and it could be able to irrigate an area of about 1 ha and it will be applied to an area of 10913 ha). This scenario provided the third largest positive effect (3$^{rd}$ rank) via the second greatest impact after Scenario 6 in increasing water yield (4%) and it would be able to decline AFC by 32.0%, maximum discharge 4.70% and RRC 21.2% as well as increasing average discharge 3.21%, minimum debit 23.53%.

Scenario 4 (the combination of scenario 1 and 2 with a total improvement area of 13852 ha) got ranked 4th and it could be able to reduce AFC by 28.0%, maximum discharge 7.67% and RRC 23.0% and to increase the average discharge by 1.78%, minimum discharge 20.59% and water yield 1.4%. Scenario 5 is ranked second, best than the other six scenarios. However, land improvement management will be carried out over an area of 13852 ha. This scenario five will be able to reduce AFC by 32.0%, maximum discharge by 17.14%, RRC 34.2% and increased river flow by an average of 3.21%, minimum flow by 26.47% and increased water yield by 3.9%. Scenario 6 is the best scenario compared to the other six scenarios, it is placed in rank 1st. Land improvement management will be carried out over an area of 12,912 ha. This scenario 6 will reduce AFC by 36%, maximum discharge by 16.31% and RRC 34.6% and increased river flow by an average of 3.45%, minimum flow by 29.41%, and water yield by 4.2%.

### *3.4. Consideration in the selection of Cilemer watershed management recommendations*

From the simulation and scoring results, Scenario 5 and 6 provide the highest LMIPA and score, it can be nominated as the best scenario to improve Cilemer watershed quality. However, Scenario 5 and 6 would not be necessarily selected the best scenario if the various aspects or other factors which become the main purpose and/or priority along with the way to deal with implementation limit are considered in the decision making.

In assisting and facilitating to choose the best scenario by considering various ultimate factors, then it is necessary to examine the advantages and disadvantages from the application of each scenario that can be seen in Table 11. Scenario 5 and 6 promise the highest contribution in watershed quality improvement, but it also demanded much heavier input and large improvement areas and becoming the expensive scenarios. Comparing with the score of Scenario 2 which has much lesser or lighter input and much smaller improvement area, Scenario 2 could be considered as the most optimal scenario if the long-term effect is still accepted.

**Table 11** Some advantages and disadvantages from the application of each scenario

| Scenario | LMIPA (ha) | Score* | Advantages | Disadvantages |
|---|---|---|---|---|
| Scenario 1 | 13852 | **+5** | Cheap | Smallest in increasing agricultural productivity |
| Scenario 2 | 1999 | **+3** | 1. Cheapest smallest area<br>2. Increased agriculture income | Long-term effect |
| Scenario 3 | 10913 | **+5** | Increased agricultural productivity | |
| Scenario 4 | 13852 | **+5** | Increased agricultural productivity | |
| Scenario 5 | 13852 | **+5** | 1. Increased water supply<br>2. Increased agricultural productivity<br>3. Short-term improvement effect | Expensive |
| Scenario 6 | 12912 | **+5** | 1. Increased water supply<br>2. Increased agricultural productivity<br>3. Increased agriculture income<br>4. Short-term and long-run improvement effect | The most expensive |

LMIPA=Land Management Improvement Plan Area
*obtained from various scenario effect toward the surface flow, river discharge, and water yield (Table 9)

## 4. Conclusion

Cilemer Watershed is in critical condition, it is shown by its RRC value, 119.7 which is categorized as very bad. Land use of Cilemer watershed is dominated by dryland farming, dry land mixed farm and agricultural plantation (81.83% of total area) which were not managed according to appropriate soil-water conservation techniques is the main source of degradation of Cilemer Watershed. The increase of the Water Use Index from 0.47 in 2011 to 0.85 in 2015 is presumed by declining water supply and availability due to the poorer quality in the Cilemer Watershed.

Scenario 6 produced the highest watershed quality improvement effect, but Scenario 2 is the most optimal. The selection of the best scenario can be adjusted to the objectives, advantages and disadvantages of each scenario as well as the terms and availability of support for executing the scenario.

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