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Characteristics of Watershed For Determination of Critical Land Management: Application of Model Of Soil And Water Assesment Tool In Sub Watershed Ciseel, Watershed Citanduy, West Java Province, Indonesia

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Abstract
Sub watershed Ciseel is one of the sub watersheds in the area of watershed Citanduy which exhibited important role in the life and economy of the people. The objectives of this research were to learn the productivity level of sub watershed Ciseel to produce water, and to learn the sediment yield which affected the quality of Ciseel river. Data analysis used Soil and water Assesment Tool (SWAT). Research results showed that most (around 46%) of Ciseel river flow in the upstream, middle and downstream part, came from surface runoff. Of the sub surface flow, lateral flow was more dominant as compared with ground water flow in the upstream part. Contribution of lateral flow was around 29,9%, whereas that of groundwater flow was around 24,5%. For the middle part, ground water flow (29,5%) was more dominant as compared with lateral flow (23,7%). Unlike with downstream part, comparison between groundwater flow and lateral flow, shows that they were relatively similar, namely around 23.3%. Sediment yield in sub watershed Ciseel was still categorized as safe. Around 98.12% of the sub watershed Ciseel area, exhibited sediment yield less than 60 tons/Ha/year. Land with erosion rate of more than 60 tons / ha/ year in sub watershed Ciseel was approximately 1402 hectares. The greatest sources of erosion came from bare land, dry land agriculture and shrub land in slope of more than 15%.
Keywords: *Sub watershed Ciseel, sediment yield, surface flow, groundwater flow, lateral flow, SWAT*

1. Introduction

Watershed is a land area which is topographically bordered by mountain/hill ridges, which collects and stores rain water which will be further channeled to sea through main river (Asdak, 2004). In the context of hydrology, watershed possesses biophysical characteristics which are related with topography, morphometry, meteorology, land uses, and slope condition. Those biophysical features would determine the amount of evapotranspiration, run-off (*surface flow*), subsurface flow (*lateral* and *groundwater flow*), and erosion rate.

Sub watershed Ciseel constitutes a part of watershed Citanduy which is categorized as critical. This is shown by the great fluctuation of river flow (water yield). During dry season, water is very little, even in several areas of sub watershed Ciseel. Drought frequently occurs, such as in areas Paledah, Sindangwangi, Sukanegara and Ciganjeng whose area size reach 1.316,63 Ha. On the other hand, during rainy season, several areas, such as South Lakbok, has around 50% of its area flooded (BBWS Citanduy, 2014).

Such phenomena shows a change in the allocation and distribution of water. In the rainy season, more water should be stored as ground water recharge and removed during the dry season. In fact, more rain water into the surface water caused flooding and drought in the dry season. Therefore it is necessary for a quantitative research to determine the level of productivity in the sub watershed Ciseel water production by knowing how much of each water yield component (*surface flow, lateral* and *ground water flow*) contribute to the flow of the river and the level of sediment yield from the land affects Ciseel water quality. Quantification of the hydrological variables can be used as consideration by decision makers (*Policy Makers*) as basis for critical land management and evaluation of watershed.

2. General Description of The Research Location

The location of this research is in sub watershed Ciseel. Geographically, the area of sub watershed Ciseel is situated in coordinate 108°13'51''-108° 43'15''E and 7°20'37''- 7°34'20'' S. The area size of watershed Ciseel was around 78.337 ha. Administratively, sub watershed Ciseel belongs to regency (district) of Ciamis (66,9%), regency of Tasikmalaya (21,95%), city of Banjar (8,2%) and city of Tasikmalaya (2,94%), (Figure 1).

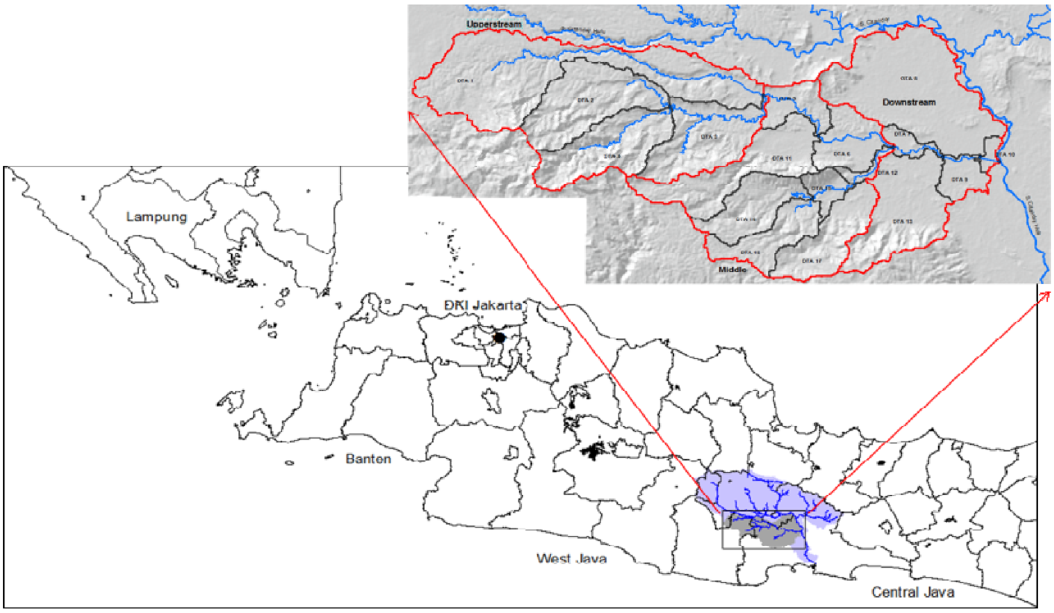


Figure 1. Research Location

Average air temperature in the lowland of sub watershed Ciseel is around 20-34° C, whereas that in the high elevation area is around 18-22°C. Average annual rainfall is around 2.735 mm. The highest rainfall occurs in December, whereas that of the lowest in August-September. Average air humidity in the area of sub watershed Ciseel ranges between 85% - 91,71%.

Characteristics of Hydrologic Response Unit (HRU) is determined by land cover, soil type, and slope. Land cover in sub watershed Ciseel is dominated by farm field / plantation (43%), rice field (27%), settlement (11%) and forested land (13,3%). In the area of sub watershed Ciseel there are 5 dominant soil association types, namely *Tropaquepts; Fluvaquents; Tropohemists* (24,87%), *Dystropepts; Humitropepts; Tropohumults* (13,79%), *Tropudults; Dystropepts* (13,92%), *Dystropepts; Tropudalfs; Humitropepts* (13,04%) and *Dystropepts; Tropudults; Troporthents* around (12,70%). On the basis of *Soil Hydrological Group* (SHG), the area of sub watershed Ciseel is dominated by soils with low rate of water infiltration (SHG C), namely around 73,30%. Level of soil erodibility is dominated by light category (69,10%) while land slope is dominated by slope class flat/level (48,94%) and gently sloping (20,5%). Land with very steep slope is relatively small, only around 2,75%.

3. Research Method

3.1. Types of Data

Rainfall data were obtained from daily rainfall and climate of year 2009–2013 from 5 stations in the area of sub watershed Ciseel, namely Cineam, Sidamulih, Langensari, Padaringan and Gunung Putri stations. Calibration used data of water yield of Ciseel river and monthly average sediment yield of year 2011-2013 from River Flow Observation Station Ciseel in Ciawitali (coordinate 7°27'6.03"S and 108°39'17.00"E). Spatial data being used in this research are presented in Table 1.

Table 1. Spatial data being used in this research

Spatial data	Data type	Scale / Resolution	Source
DEM	Raster	90 m	SRTM (http://srtm.csi.cgiar.org/SELECTION/inputCoord.asp)
River network	Line	1:25.000	RBI *Badan Informasi Geospasial (BIG)* (Geospatial Information Agency)
Location of rainfall station	point	-	*BMKG-BBWS* Citanduy
Location of River Flow Observation Station Ciawitali	Point	-	*BBWS* Citanduy
Land cover of year 2013	Polygon	1:25.000	*Bappeda* (Regional Development Planning Agency) of West Java Province.
Soil	Polygon	1: 250.000	*Puslit Tanah* (Soil Research Center) , Bogor

3.2. Method of Analysis

3.2.1. SWAT Model

Analysis of water balance and sediment yield used SWAT model 2012 rev 635. SWAT model used the concept of water balance to explain hydrological process which was mathematically formulated as follows (Gassman *et al.*,2007, Neitsch *et al.*, 2005, and Di Luzio *et al.*, 2004):

$$SW_t = SW_{t-1} + Rday_t - (Qsurf_t + Ea_t + Wseep_t + Qgw_t)$$

Where, $SW_{t=}$ soil water content at time t (mm); $SW_{t-1\,=}$ soil water content at time t-1; $Rday_{t\,=}$ rainfall at time t; (mm) $Qsurf_{t\,=}$ run-off at time t (mm); $Ea_{t\,=}$ actual evatportranspiration at time t; $Wseep_t$ = soil water percolation from soil layer to aquifer at time t (mm); $Qgw_{t\,=}$ ground water flow at time t (mm), and t in daily terms

Sub watershed Ciseel characteristics seen from the amount of sediment, *evapotransiration* and water yield component (*surface flow*, later and *ground water flow*). In the SWAT model, potential evapotranspiration calculation using the Penman-Monteith-FAO model (Allen *et al.*, 1998). The actual evapotranspiration calculated from the amount of evaporation of precipitation retained by the canopy, transpiration from vegetation and evaporation from the surface of the soil and water bodies. To calculate the surface ru-off in each Hydrologic Response Unit (HRU) using SCS model (SCS, 1972, Rallison and Miller, 1981). Percolation is vertical movement of water between the layer of soil. In the SWAT model, percolation is calculated every layer of soil with storage routing method. Shallow layer of soil percolation in the watertight/waterproof and slope will cause lateral flow occurs. SWAT model calculates the *lateral flow* by adopting *kinematic storage model* (Sloan and Moore, 1984). Water percolation of soil layers, then into aquifer (*ground water storage*). Venetis (1969) and Son Grey et al. (1984) has formulated the amount of water entering the groundwater storage of the soil profile. Calculation erosion of any SWAT HRU in the model using a formula Modified Universal Soil Loss Equation (MUSLE) of Williams (1995). MUSCLE is a formula that has been modified from USLE (Wischmeier and Smith, 1978)

3.2.2. Warming up and Calibration

Warming Up of SWAT Model was conducted in the period of year 2009-2010 (2 years), whereas calibration period was in the year 2011– 2013 (3 years). Calibration used SWAT-CUP (Abbaspour *et al.,* 2008) with algorithm of *Sequential Uncertainty Fitting Ver.*2 (SUFI2) as has been conducted by Schuol *et al*. (2008).

Calibration of model with observation data used determination coefficient (R^2) and *Nash-Sutcliffe model Efficiency (*NSE*) coefficient* (Nash dan Sutcliffe, 1970) as objective function (Abraham *et al*. 2007). Values of R^2 and NSE described the relation between simulation results and observation results. R^2 took the values between 0-1 and NSE had values between -∞ and 1. If the values of R^2 and NSE approach 1, the model is categorized to be progressively better.

4. Results And Discussion

4.1. Calibration of Model

Calibration period of year 2011 – 2013 used monthly average data. Calibration used 7 parameters of model, namely ALPHA_BF, GW_DELAY, CH_N2, CH_K2, CH_K1, CH_N1 and SURLAG. Of the total number of 400 iterations, best result in the calibration process was obtained in the 349th iteration. Statistics of results of calibration between output of SWAT model and observation data using SWAT CUP are presented in Table 2, whereas the best fitting results are presented in Table 3. Values of NSE for calibration of river water yield was around 0.80, which was relatively better as compared that of sediment yield calibration (0.61). Also, for values of p-factor, at 95% confidence interval of the model, around 56% of data of river water yield observation, were within the range of model uncertainty. On the other hand, the corresponding value for sediment yield was around 32%. Comparison of results of SWAT model and observation data in time series manner, is presented in Figure 4.

Table 2. Recapitulation of statistic parameters for model evaluation

Variable	p_factor	r-factor	R^2	NSE	bR^2	MSE	SSQR
Yield (m3/s)	0.56	0.44	0.81	0.80	0.6	140.8	51.03
Sediment (ton/Ha)	0.32	0.30	0.65	0.61	0.52	154.7	60.1
p_factor	Measured data bracketed by the 95PPU (max value 1)						
r-factor	Measure of the quality of the calibration and indicates the thickness of the 95PPU						
R^2	Determination Coefficient						
NSE	Nash Sutcliffe Coefficient						
bR^2	Weight of determination coefficient (R^2) with slope (b)						
MSE	Multiplicative of the sum of error						
SSQR	Sum Square of Error						

Source : Data, processed

Table 3. Model parameters subjected to calibration

Parameter_Name	Keterangan	Fitted Value	Min Value	Max Value
1: V__ALPHA_BF.gw	Base flow alpha factor (days)	0.8	0	1
2: V__GW_DELAY.gw	Groundwater delay (days)	10.0	0	60
3: V__CH_N2.rte	Manning's "n" value for the main channel	0.1	0	0.3
4: V__CH_K2.rte	Effective hydraulic conductivity in main channel alluvium	50.8	5	130
5: V__CH_K1.sub	Effective hydraulic conductivity in tributary channel alluvium	190.0	0	300
6: V__CH_N1.sub	Manning's "n" value for the tributary channels	17.0	0.01	30
7: V__SURLAG.bsn	Surface runoff lag time	1.6	1	2

Source : Data, processed

Figure 3 shows the relation between river water yield and sediment yield as output of the SWAT model, and observation, in the form of positive linear graph with determination coefficient (R^2) as large as 0,8112 (n=36). Comparison with line y=x (Qobs=QSWAT model), shows that average of the model output is 5.3 % higher relatively, as compared with yield of observation results. On the other hand, relation between sediment yield as output of the SWAT model, and observation, possessed determination coefficient as large as 0,6479 (n=36). Comparison with line y=x, shows that average of model output is 12.2% higher relatively from sediment yield obtained from observation. To simulate river flow showed very good results, while the results of sediment good (Moriasi et al., 2007)

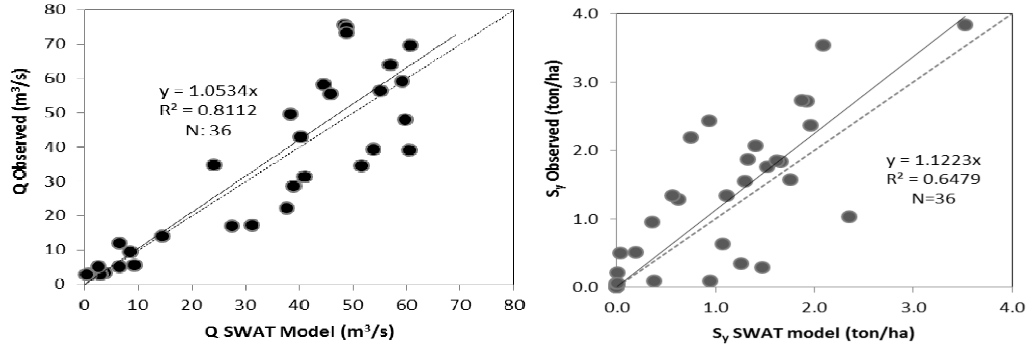


Figure 3. Comparison between results of SWAT model and observation data, and line y=x. Left figure for river water yield. Right figure for sediment yield.

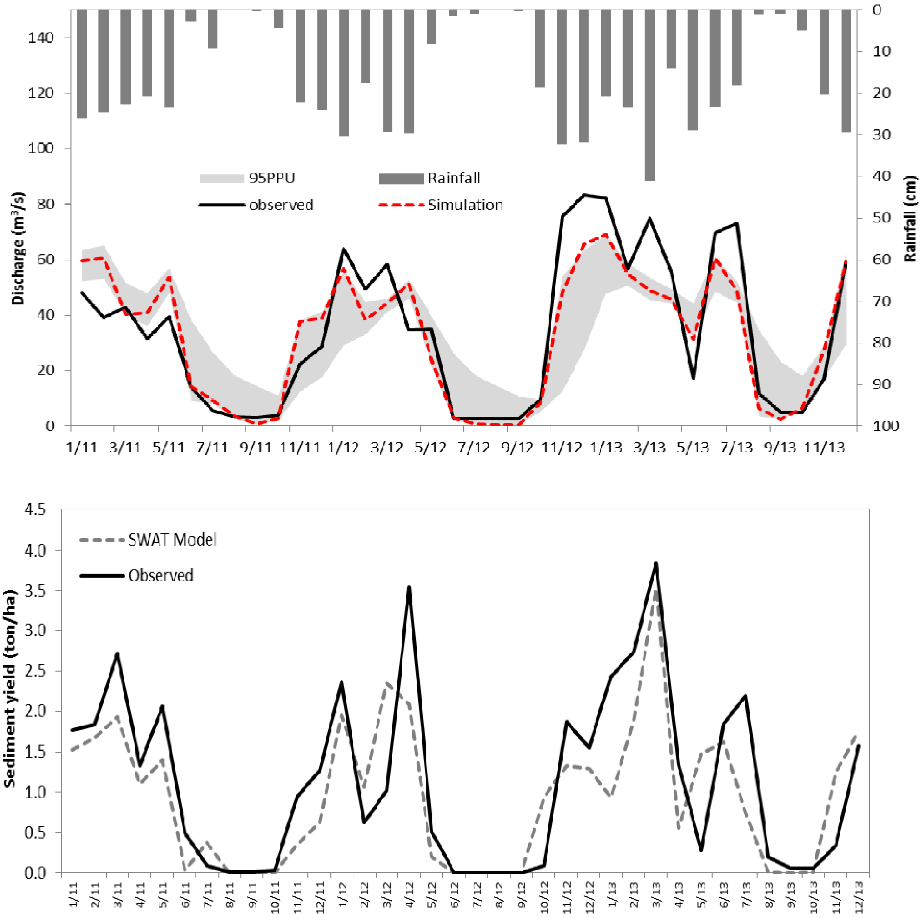


Figure 4. Comparison between results of SWAT model (river water yield and sediment yield) and observation data, with range of 95PPU, and respond of the model toward rainfall.

In the analysis of model sensitivity, it was learnt that of the 7 parameters being calibrated, rainfall _K2 and ALPHA_BF were more sensitive as compared with other parameters. This was shown by the P-Value which was the least (approaching 0) or by the t-stat absolute value which was the largest. P-Value limit~0 or |t-Stat|≈max shows that the model parameter is more sensitive (Figure 5).

Each parameter is calibrated, has a different sensitivity level in the calculation of hydrological processes. Small changes in the value of the parameter is causing major changes to the results ahir model (eg discharge in the river). This can be seen from the Value P-Value or t-Stat (Abbaspour, 2008). In a sensitivity analysis of the model, it is known that from 7 parameters are calibrated which included highly sensitive (most sensitive) if P-

Value of less than 0.05 is CH_K2 and ALPHA_BF parameters and the absolute value of the t-stat of the greatest (Figure 4).

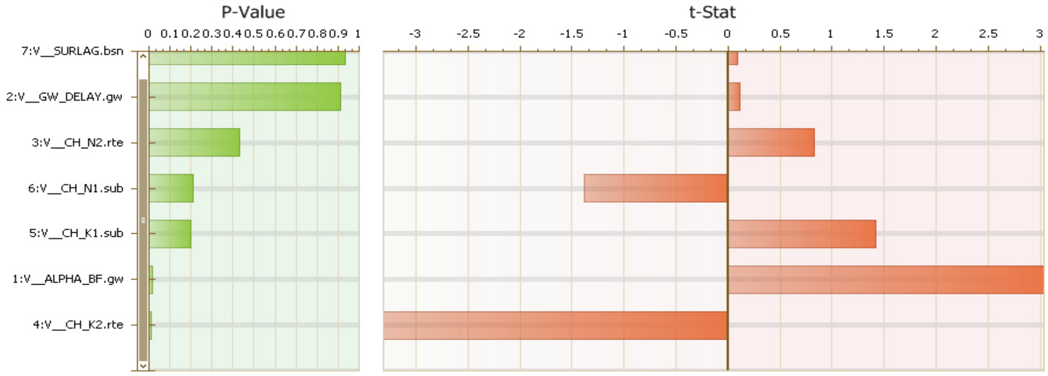


Figure 5. Calculation results of P-Value and t-Statistic to examine which parameters are very sensitive during the calibration process

4.2. Hydrologic Terrain

Area size of sub watershed Ciseel is around 78.337 Ha, divided into 17 sub basins (Figure2). Morphometry of sub watershed Ciseel is divided into 3 parts. The upstream part comprises 4 sub basins, as large as 32.405 Ha; the middle part comprises 8 sub basins, as large as 24.277 Ha; and the downstream part comprises 5 sub basins, as large as 21.707 Ha. Morphometric condition of each water catchment area is presented in Table 4.

Table 4. Recapitulation of morphometric condition of each Water Catchment Area in sub watershed Ciseel

Sub basin	Parameters of Water Catchment Area							
	Area[1]	Slo1[2]	Len1[3]	Sll[4]	Csl[5]	Elev[6]	ElevMin[7]	ElevMax[8]
	(Ha)	(%)	(Km)	(m)	(%)	(m asl)	(m asl)	(m asl)
1	14572	10.7	43.04	61.0	2.2	284	21	972
2	6494	16.6	18.94	18.3	4.4	339	58	975
3	5706	15.0	19.22	24.4	3.5	173	27	707
4	5632	24.4	18.59	15.2	5.0	447	59	1112
5	2117	7.9	10.83	61.0	0.6	60	16	333
6	3047	7.2	11.04	61.0	2.6	43	10	427
7	884	4.6	8.72	91.4	0.5	22	6	90
8	12073	4.1	19.74	91.4	1.3	25	1	360
9	1517	2.9	9.25	91.4	0.1	15	5	56
10	449	2.2	4.41	91.4	0.2	12	4	25
11	6168	14.5	24.46	24.4	2.7	246	13	707
12	534	6.9	8.02	61.0	3.3	48	16	270
13	6783	11.6	21.32	61.0	2.8	138	7	662
14	3709	14.4	14.90	24.4	3.1	263	32	499
15	1214	14.2	7.16	24.4	5.7	114	19	448
16	3232	12.3	14.69	24.4	3.0	286	31	514
17	4206	15.4	16.68	24.4	2.6	208	16	572

Source : Output of terrain analysis SWAT
Notes : 1. Area size of land, 2. Average of land slope, 3. Length of the farthest flow from outlet location , 4.Average length of slope, 5. Average slope of river route, 6. Average elevation of land, 7. minimum elevation, 8. maximum elevation

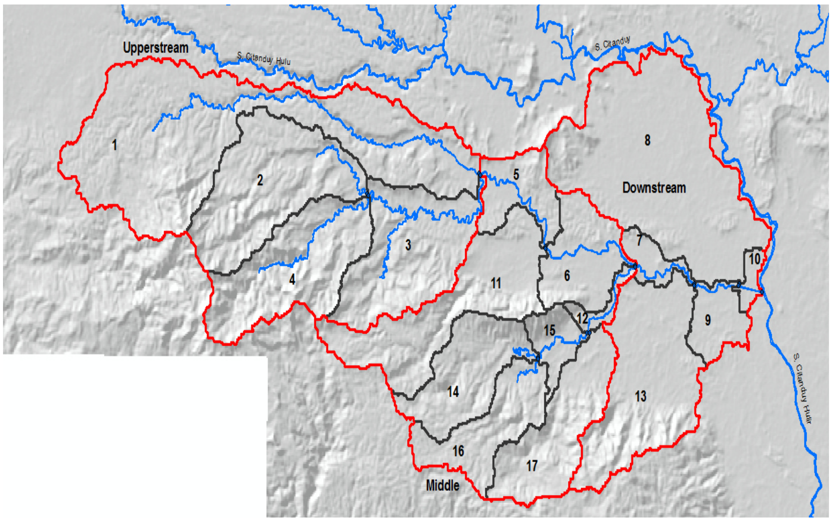


Figure 6. Division into sub basins as output of terrain analysis using SWAT in sub watershed Ciseel.

4.3. Hydrologic Condition

Land cover condition; soil types, and slope condition would determine the hydrologic condition of the water catchment area. These hydrological characters would determine the amount of water yield being produced and the composition of the flow (surface flow, lateral flow or base flow), and the amount of sediment yield. Amount of rainfall being received as input, will be in balance with the amount of water which goes out, plus the amount of water being stored in the soil (storage). Water which goes out comprise evapotranspiration, surface flow, lateral flow and ground water flow. Water which undergoes evapotranpiration will be lost to the atmosphere. Surface flow, lateral flow and ground water flow will contribute to the river flow (stream flow). Amount of water which contributes to the river flow is referred to as water yield.

Based on data of the past 5 years from 5 rainfall stations around the sub watershed Ciseel, it was known that the upstream part of the watershed received higher rainfall as compared with those of the middle part and the downstream part. Average amount of rainfall in the upstream part was around 2.520 mm, that in the middle part was around 2.291 mm and that in the downstream part was around 2332 mm annually.

For comparative purposes, distribution of water balance components in sub watershed Ciseel is shown in Figure 7 and 8. Composition of water flow which was discharged from sub basin, either in the upstream, middle and downstream part was dominated more by surface runoff, followed in decreasing magnitude by evapotranspiration, ground water flow and lateral flow. Amount of evapotranspiration in the upstream, middle and downstream part were relatively similar, with average ranging between 558-575 mm annually. In terms of proportion as compared to the rainfall, evapotranspiration ratio was around 22-23%. Proportion of surface flow in the upstream part is relatively similar with that in the downstream part, namely around 34,7%, whereas that in the downstream part was around 35,4%. Ratio of ground water flow in the upstream part was relatively smaller (18,6%) as compared with that in the middle part (22,2%) and downstream part (20,8%). This was due to condition of land physiography which was more sloping. On the other hand, the ratio of *lateral flow*, in the upstream part was relatively higher (22,7%) as compared with those in the middle (17,9%) and downstream part (20,7%).

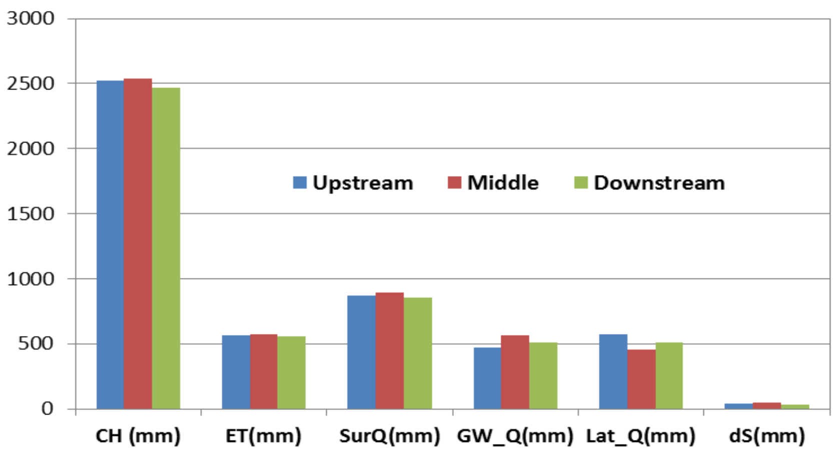
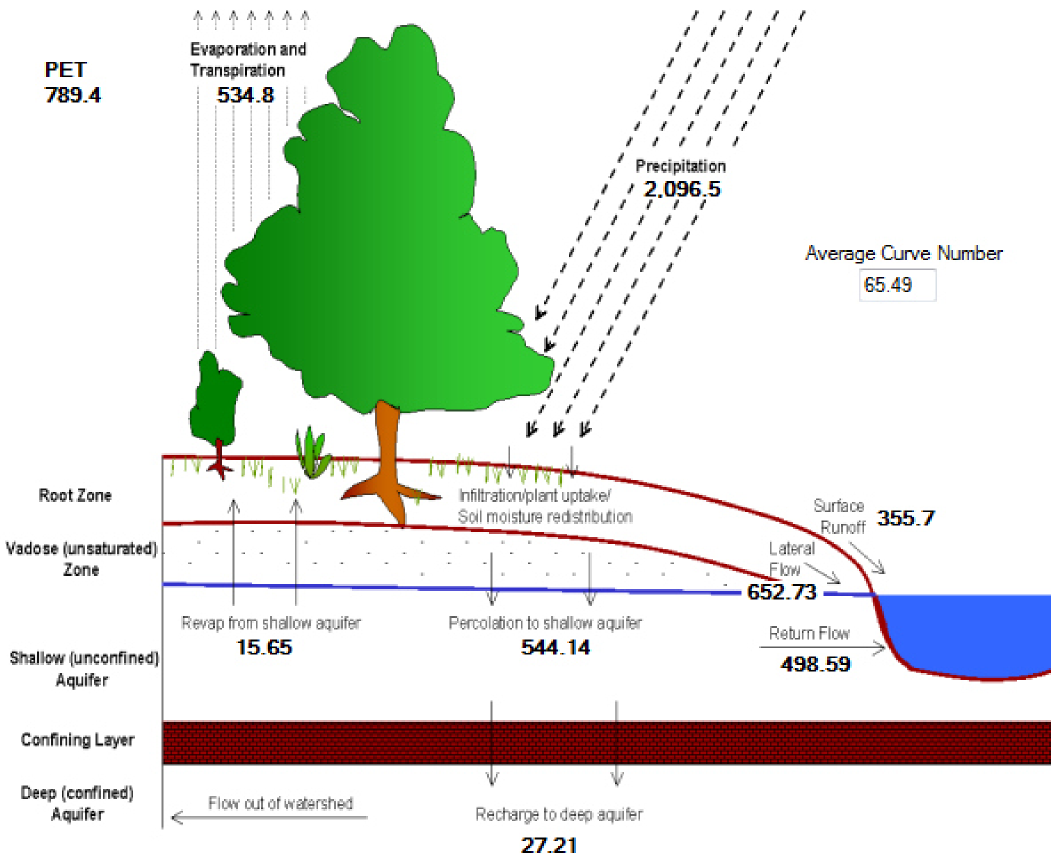


Figure 7. Distribution of water balance condition in sub watershed Ciseel



(Average condition for 5 years)

Figure 8. Comparison of composition of water balances in sub watershed Ciseel

Figure 9 shows the composition of water sources which contribute toward water flow of Ciseel river. Ciseel river flow, either in the upstream, middle, and downstream part mostly came from surface runoff (surface flow), namely around 46%. Of the sub surface flow, lateral flow was more dominant as compared with ground water flow in the upstream part. Contribution of lateral flow was around 29,9%, whereas that of groundwater flow was around 24,5%. For the middle part, ground water flow (29,5%) was more dominant as compared with lateral flow (23,7%). Unlike with the downstream part, comparison between groundwater flow and lateral flow , shows that they were relatively similar, namely around 23.3%.

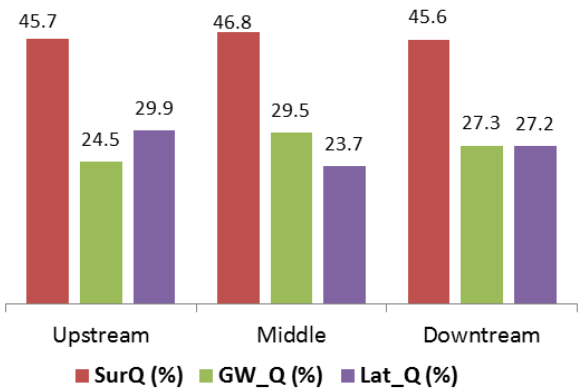


Figure 9. Comparison of water yield composition in sub watershed Ciseel

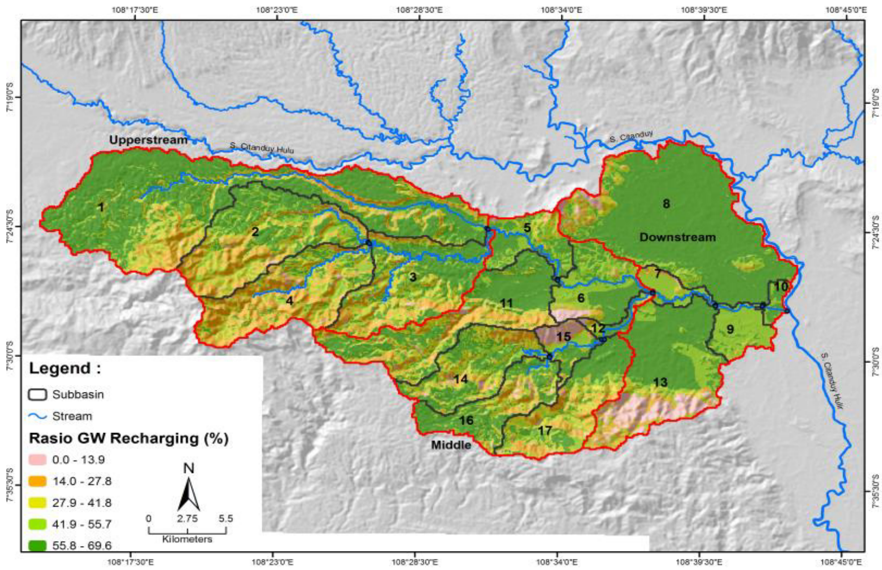


Figure 10. Potency of the magnitude of ground water recharging ratio toward the amount of rainfall in sub watershed Ciseel.

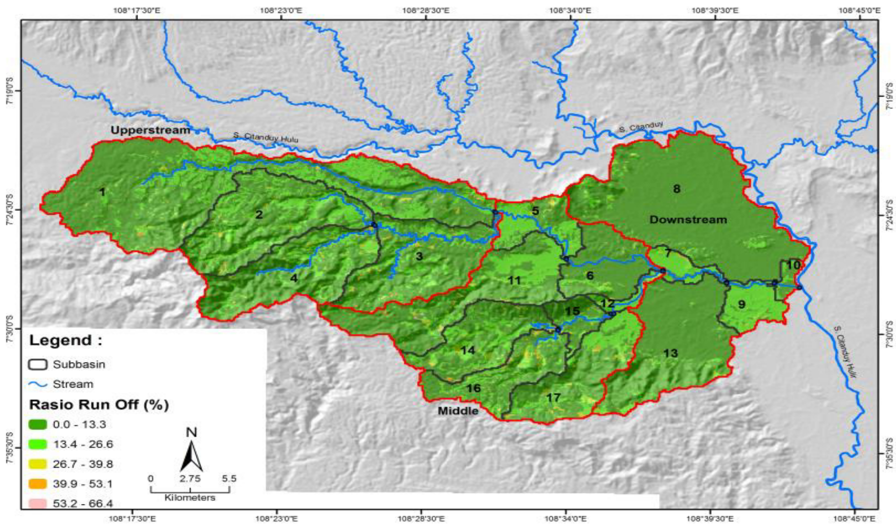


Figure 11. Potency of the ratio of run-off to the amount of rainfall in each HRU which contribute toward river flow in sub watershed Ciseel.

The composition of water sources shows that sub watershed Ciseel possessed high productivity as supplier of water for its downstream area. Composition of water yield which came from dominant (54%) subsurface flow, showed that water catchment area in each land unit had great role in providing groundwater recharge. Distribution of the amount of groundwater recharge in sub watershed Ciseel, as SWAT output is shown in Figure 10. Relatively level land condition (slope less than 15%) with vegetation, possessed great potency for groundwater recharge. On the other hand, distribution of runoff ratio to the amount of rainfall in each area of HRU is shown in Figure 11. Average ratio of runoff to the amount of rainfall was around 13-26%.

4.4. Erosion Rate

In general, condition of erosion rate in sub watershed Ciseel was categorized as safe. Around 94% was categorized as very low (less than 15 tons/ha/year), 4.18% was categorized as low (15-60 tons/ha/year), and 1,67% was categorized as moderate (60-180 ton/Ha/year). Only very little was categorized as heavy and very heavy (more than 180 tons/ha/year), namely around 0.12%. Recapitulation of area classification on the basis of erosion rate classes in sub watershed Ciseel is presented in Table 5, and distribution of sediment yield in each HRU is presented in Figure 13.

Table 5. Land area size (ha) for each category of sediment yield (tons/ha/year)

Land area size. Subbasin	Very low (0-15)	Low (15-60)	Moderate (60-180)	Heavy (180-480)	Very heavy (> 480)
1	14,218	300	54	1	0
2	6,110	291	93	0	0
3	5,312	313	81	0	0
4	5,383	180	69	1	0
5	2,003	85	29	0	0
6	2,918	65	54	10	0
7	827	35	23	0	0
8	11,511	378	180	4	0
9	1,497	11	10	0	0
10	449	0	0	0	0
11	5,999	118	52	0	0
12	399	75	61	0	0
13	6,432	269	71	11	0
14	3,131	475	82	22	0
15	1,090	89	35	0	0
16	2,736	316	169	12	0
17	3,657	272	243	18	16
Total	73,671	3,271	1,306	80	16
(%)	94.04	4.18	1.67	0.10	0.02

Source: Data, processed

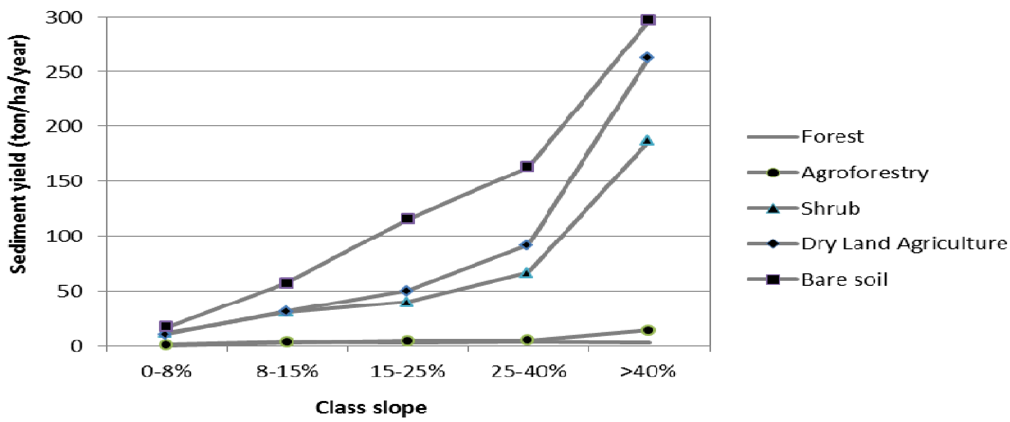


Figure 12. Average erosion rate in each type of land cover on the basis of slope class in sub watershed Ciseel.

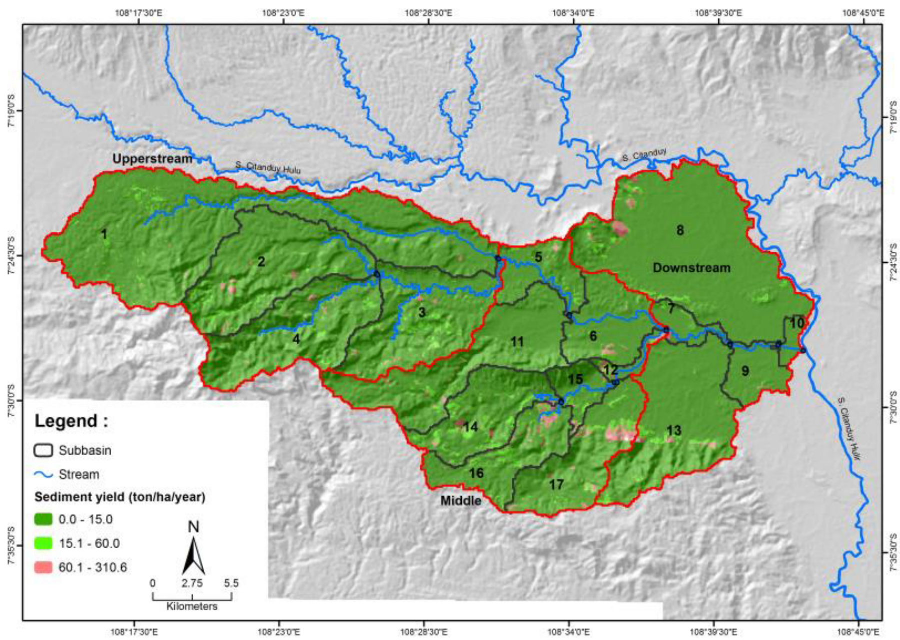


Figure 13. Potency of sediment yield in each land unit in sub watershed Ciseel

In figure 12, it could be seen that the greater the steepness of the land, the greater would be the *sediment yield*. This was shown by all types of vegetated land cover, except those of forested land and agroforestry. Sediment yield in bare land was relatively much higher as compared with other land cover, in line with increasing slope, followed with decreasing magnitude by dry land agriculture and shrub land. Forested land and agroforestry were able to retain sediment yield in sloping land. For reducing erosion rate, land cover type bare land, dry land agriculture and shrub land in slope greater than 15% need to be rehabilitated, so that their condition could resemble those of forested land /agroforestry. Size of land area which needs to be rehabilitated was around 553.4 Ha, where 34.6 ha of which, categorized as having heavy and very heavy erosion rate, needs to receive first priority, whereas the other 518.8 Ha with moderate erosion rate, receive second priority.

5. Conclusion

Ciseel river flow in the upstream, middle, and downstream part, mostly (around 46%) came from surface runoff (surface flow). Of the subsurface flow, lateral flow was more dominant as compared with ground water flow in the upper part. Contribution of lateral flow was around 29,9%, whereas that of ground water flow was around 24,5%. For the middle part, ground water flow (29,5%) was more dominant as compared with lateral flow (23,7%). Unlike with downstream part, comparison between groundwater flow and lateral flow, shows that they were relatively similar, namely around 23.3%. The small contribution of sub surface flow constituted one of the factors which cause decrease in water availability in the river during dry season.

Sediment yield in sub watershed Ciseel was still categorized as safe. Around 98.12% of the sub watershed Ciseel area, exhibited sediment yield less than 60 tons/Ha/year. Land which needs handling priority in sub watershed Ciseel is that with erosion rate of more than 60 tons/ha/ year, comprising area of around 1.402 ha, while land with erosion rate of less than 60 tons/ha/year needs to be maintained.

The greatest sources of erosion came from bare land, dry land agriculture and shrub land in slope of more than 15%. To improve water condition in sub watershed Ciseel, there is a need for rehabilitation of dry land agriculture, and shrub land in land with slope greater than 15% whose areas size was around 553.4 ha. Besides that, there is a need to construct pockets of ground water recharge in open and flat land to increase supply of sub surface water flow, so that sub watershed Ciseel could be more *sustainable*.

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