SPATIAL PATTERN OF HYDROLOGIC RESPONSE UNIT (HRU) EFFECT ON FLOW DISCHARGE OF CI RASEA WATERSHED USING LANDSAT TM IN 1997 TO 2009

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Abstract. Hydrologic Response Unit (HRU) is a unit formed of hydrological analysis based on geology and soil type, slope, and land cover. This paper discussed the spatial pattern of Hydrologic Response Unit (HRU) in 1997-2009 and its impact on flow Ci Rasea watershed temporally. In this study, SWAT (Soil and Water Assessment Tool) model, based on land cover changed, was used to get HRU and flow in spatially and temporally. This method used Landsat TM 1997, 2003 and 2009 data for land cover and daily rainfall 1997-2009 for flow modeling. The results showed the spatial pattern of HRU in temporally was affected by landcover based on the changing of HRU. The majority of HRU spatial pattern at Ci Rasea watershed were clustered. During 1997-2009, accumulated surface runoff and the changing of flow discharge were affected by changes of HRU spatial pattern. The biggest accumulated surface runoff in Ci Rasea watershed influenced by HRU of agricultural cropland in area of clay soil type with slope slightly obliquely. While the smallest accumulated surface runoff in Ci Rasea watershed influenced by HRU of paddy field in the area of sandy loam soil type with a gentle slope. The changes of HRU agriculture cropland become HRU mixed cropland in area clay soil type with slope at a slight angle and HRU agriculture cropland become HRU paddy field in area, sandy loam soil type with a gentle slope could be decreasing the accumulation of surface runoff in Ci Rasea watershed.

Keywords: *Ci Rasea watershed, HRU, surface runoff, SWAT model, landcover*

1 INTRODUCTION

Land cover changes become built up area caused the higher risk of flooding due to the ability of land to absorb water and river capacity to accommodate streams of water is decreasing (Chubey and Harhout, 2004). The decreasing of river capacities was caused by silting, land, converting and over groundwater using in the catchment area. Land cover changes in the upstream region such as forest becoming settlements or open land, also affected by the flood. It will cause the increasing of runoff due to the area of water catchment was reduced. Beside that the precipitation, topography, soils, geology and land use, which are heterogeneously distributed within the watershed controlling infiltration, surface runoff and évapo-transpiration (Anderson and Burt, 1978; Beven and Kirkby, 1979; Devito *et al.* 2005).

Ci rasea is one of the area upstream Ci Tarum watersheds. According to Joseph (2010), land cover Ci Rasea basin in the years 1997-2007 has undergone a change. According Balitklimat (2007) and Pawitan (2002 and 2006), land cover change occurs in the headwaters of a watershed (DAS) leads to changes the hydrological characteristics. According Harto (1993), the changes of hydrological characteristics occurred in the form of surface water behavior and function such as increasing of flow due to the decreasing of infiltration capacity which causes flood occurred.

Hydrological characteristics can be generated from the analysis of hydrologic response units (Hydrologic Response Unit/HRU). Hydrologic Response Unit (HRU) is a unit of hydrological analysis based on geology and soil type, slope, and land cover. According Flugel (1997), analyzes of HRU can produce spatial facts and phenomena that exist within the scope and relationship of sub-basins. HRU classified fisiogeografi characteristics based on the association of soil type, slope, geology and land cover in one area. Because of the type of soil, slope, geology and land covers are variable dynamic then it is caused HRU changes. HRU changes commonly occur due to the needed of land for settlements and others. According to Rodriguez-Iturbed and Valdes (1979), the underlying unity in the nature of the geomorphologic structure is thus carried over to the great variety of hydrologic responses that occur in nature.

Hydrology model which can be used to obtain hydrological characteristics of the watershed is Soil and Water Assessment Tool (SWAT). According Neitsch, *et al.* (2005) SWAT is a model that can be used to predict the effects of land cover on water flows, sediment, and other substances that enter the river or body of water in a watershed. Other studies said that SWAT can describe the relationship of land cover on watershed hydrology (Hernandez *et al.*, 2000; Suryani, 2005; Briley, 2010; Arnold, 2011 and Adrionita, 2011; Leon and George. 2008; Park *et al.*, 2011).

HRU changes due to Land cover changes can increase risk of flooding and reduce the ability of land to absorb water and the capacity of the river to accommodate flow discharge. Based on previously studied, the combination of HRU and rainfall as input for SWAT models expected could be used to produce flow discharge in watershed or sub-watershed. Therefore, the objective of the research is to analyze the spatial patterns of hydrologic response units (HRU) and flow discharge using SWAT models in DA Ci Rasea in 1997 to 2009.

2 MATERIALS AND METHODOLOGY

Research was carried out in Ci Rasea watershed, West Java (Figure 2-1). This research used tabular and spatial data which processed base on remote sensing and Geographic Information System (GIS). The spatial data were included map of soil characteristics with a scale of 1: 100,000, which contains type and soil texture, from Puslittanak 1993, lithology and geological data were obtained from the geological map with a scale of 1: 1000.000 which produced by the Ministry of Energy and Mineral Resources and Landsat data which used for land cover classification. The Landsat TM imagery used in this study is August 16, 1997, January 10, 2003 and November 2, 2009. The Landsat image is obtained from the USGS Global Visualization Viewer (Glovis) and National Institute of Aeronautics and Space (LAPAN). This research used topographic data such as digital elevation models (DEM) generated from the image shuttel Radar Topography Mission (SRTM). SRTM imagery has a spatial resolution of 25 meters was also obtained from LAPAN.

The tabular data used in this research are climate data such as temperature, solar radiation and wind speed was obtained from the National Climatic Data Center (NCDC). The daily rainfall data were obtained from the Ministry of Public Works (PU) in years 1997 to 2009. Hydrological data in the form of daily discharge in 2009 obtained from the Ministry of Public Works (PU). River characteristic was used such as the rough and shape of the river which obtained from field surveysRiver characteristic data used to determine the roughness of manning of the channel. Otherwise, this research also used data stream, road networks and administrative boundaries which obtained from RBI maps Indonesia (RBI) issued by BAKOSURTANAL 2009.

The software used for processing of remote sensing data are ER-Mapper and Global Mapper 7.0 11 and analysis statistics used SPSS-17. Furthermore, this research used are ErcView 3.3, Map Window 4.7.5, MWSWAT, SWAT EDITOR 2005 and SWATPlot for GIS software. In broad, the stages of research method can be seen in Figure 2-2.

Figure 2-2 showed that SRTM DEM could extract the elevation information which corrected by contour RBI. The elevation information can be modeled to the slopes which classified into several classes such as flat (0% -8%), slightly tilted (8% -15%), oblique (15% -25%), steep (25% -40%) and very steep (> 40%).

Furthermore, the third of Landsat image was corrected as orthorectification, radiometric and terrain. Ortorectrification corrections are made to reduce bias due to differences in topography when the Landsat satellite records the data. The radiometric corrections are made to reduce bias due to radiometric errors and terrain correction is correct for terrain effects. After getting corrected images, the land cover classification was done by using supervised classification with the maximum likelihood method. All of the processes above are performed on Landsat imagery with three different years, ie 1997, 2003 and 2009 to obtained landcover maps.

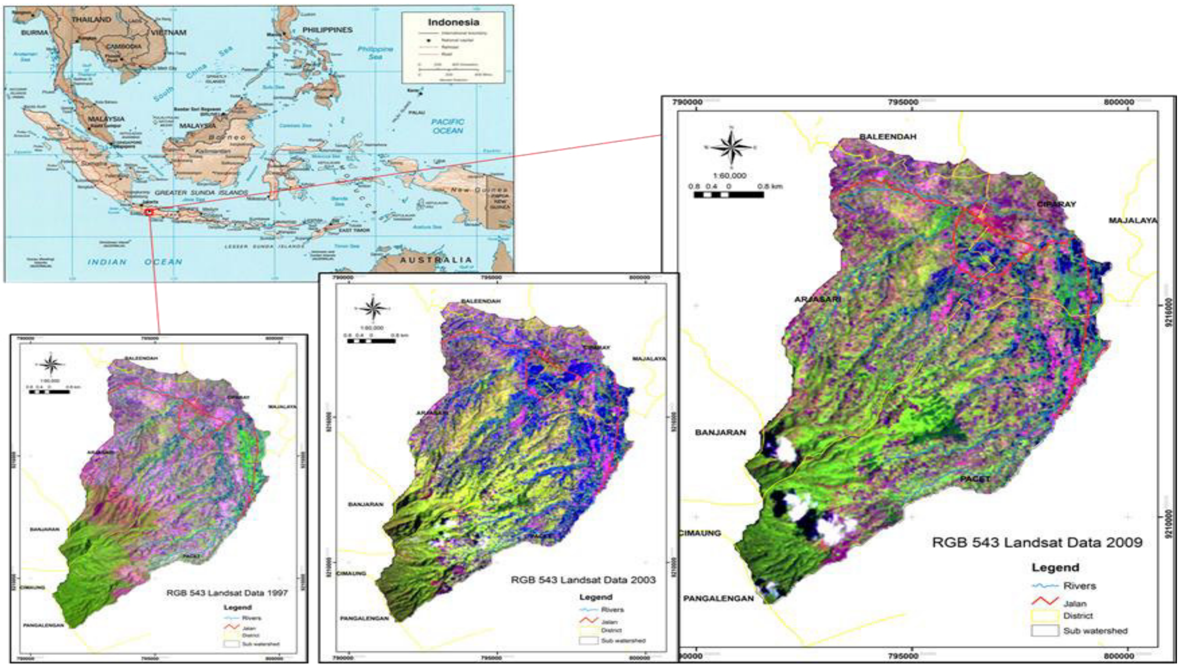

Figure 2-1: Study area, Ci Rasea Watershed base on Landsat data 1997, 2003 and 2009

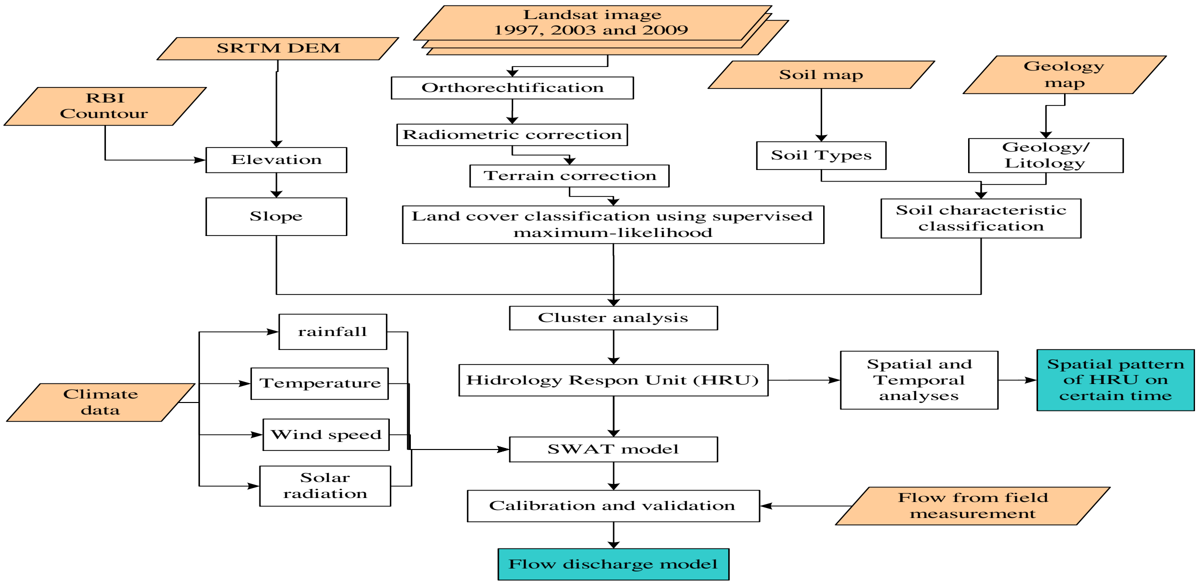

Figure 2-2: Research method flowchart

The soil types were obtained from a soil map of the Ci Rasea watershed. While the geological map carried out parent material of soil, which associated with the permeability of the soil. From the type and permeability of the soil could obtain the classification of soil characteristics in the Ci Rasea watershed. The classification consists of some classes such as class of clay (C), clayey loam (CL), clay dust (SIC), the dusty loam (SIL) and sandy loam (LS).

The first step to obtain hydrologic Response Unit (HRU) is delineated the Ci Rasea watershed by using cluster analysis. Cluster technique used is a non-hierarchical method based on the optimal value. Ci Rasea watershed delineation was conducted using the optimum value of 5 km, which means delineation detailed up to 5 km. The outlet which used in this research was Cirasea-Cengkrong gate. The HRU made based on overlay slope maps, landcover maps and map soil characteristics. In HRU process also used non-hierarchical cluster analysis method with three types of threshold percentage, such 0% for land cover, soil type 5% and 5% slope which meaning the HRU with land cover, soil and slope type smaller than the threshold will be ignored by model and the value will be replaced by the neighbors HRU. The selection of the 0 % threshold for landcover due to evaluate all of existing landcover. HRU so that changes that occur due to changes in land cover in detail can be identified. The results of the analysis of the non-hierarchical cluster method with parents are HRU DA Ci Rasea. All of the process which mentions before also performed on three years of classification in 1997, 2003 and 2009 to obtain three maps of HRU.

After getting HRU map, then performed the generating of climate data (WGN). In the SWAT model the generating of climate data should be made from temperature, rainfall, solar radiation and wind speed data. In this research used climate thirteen years data from 1997 to 2009. Data on solar radiation and wind speed are monthly average. The temperature data which are used are daily temperatures, the monthly of maximum and minimum temperature, monthly average, dew point and standard deviation of monthly temperature. While rainfall data which are daily rainfall, the average rainfall intensity in monthly, the average rainfall day in monthly, a standard deviation in monthly, skewness in monthly, chances days of rain followed by dry days, the chance of rainy days followed by days of rain and rain extremes a half day in monthly. Rainfall stations which are used in this study is Ciparay rain station due to SWAT model is using the nearest station.

Combination of HRU Ci Rasea watershed and WGN could simulation of flow model using SWAT. HRU mapping and modeling of flow performed on SWAT plugging in Map Window 4.7.5 which is called MWSWAT interface. Simulation models to obtain discharge is executed based on the input rainfall data and daily temperature from January to April in 2009. The flow simulation did again by using same rainfall and temperature for each landcover between 2003 and 1997. Thu scan be obtained spatial and temporal outcome of the HRU and flow rates in the Ci Rasea watershed. The analysis was done by observing the changes of HRU and flow in spatially and temporally. Spatial patter be categorized as:

- Random if standard deviation equal to the average,
- Uniform if standard deviation less than the average,
- Cluster if standard deviation more than the average.

Calibration and validation is performed by comparing the discharge flow models and field measurements in the same year to see how accurate the results which was obtained. Flow from field measurement is discharged in 2009 results in gate Cirase-Cengkrong, synchronous with rainfall data which was input to the model. Calibration and validation methods which are used in this study are statistical analysis based on Nash-Sutcliffe efficiency (NS) and t-test (T-student) which conducted in the SPSS-17 software.

3 RESULTS AND DISCUSSION

In spatially landcover changes in Ci Rasea watershed in 1997, 2003 and 2009 as well as changes in land cover from 1997 to 2009 can be seen in Figure 3-1. Figure 3-1 could be seen that the settlements and paddy fields were located in the downstream of the watershed. While the plantation, scrub and cropland were located on the downstream, midstream and upstream of the watershed. Furthermore, the forests were located on the upstream of the watershed.

The changes of cropland mostly happen on downstream and middle of the watershed and less on the upstream of the watershed. The Changes of forest, scrub and plantation to cropland due to they located next to cropland. So, it has been expansion or extension of cropland by converting forest, scrub and plantation in Ci Rasea watershed. The changes of others landcover into settlements, mostly occurred in the downstream of watershed and small portion occurred in central of the watershed. The changes of others landcover into a forest only occurred on upstream watershed. The changes of others landcover into paddy fields mostly found in middle and downstream of the watershed. The changes of others landcover into the scrub occurred in whole watershed.

Based on results of land cover classification using six classes of land cover (forest, plantation, settlement, paddy field, scrub and croplane) during 1997-2009 could be observed that had been so many landcover changes in Ci Rasea watershed. Increasing and decreasing the area of each land cover from 1997, 2003 and 2009 are briefly presented in Table 3-1. It appears that in 1997 and 2003 the dominant land cover was plantation and the less was a settlement. But in 2009, dominant area was the cropland. The the largest rate of land cover change during 1997 to 2009 was acquired on settlements, with increasing 49%. But in general, land cover areas which are increasing during 1997-2009 are settlements and croplands. Landcover areas were decreased in 1997-2009 is a scrub, plantation and forest.

Land cover change during 1997-2009 is not always linear, but fluctuates depend on the length of time, observation, such as land cover change occurs on paddy field and scrub. During 1997-2003 was occurred the increasing in paddy field areas, but during 2003-2009 the paddy field areas become decreasing. In addition, scrub area was decreased during 1997-2003 and increasing during 2003-2009. But in general, paddy field and scrub areas were decreasing during 1997-2009.

During 2003-2009 the largest land cover changes occur on cropland and the less was paddy field. This was indicated the changes pattern of land cover from wet farming into dry farming in Ci Rasea watershed. Because during 1997-2003 paddy fields were increased, but the inverse happens during 2003-2009 while the cropland increased. Increased settlement during 1997-2009, indicates that the population growth occurred at that time in Ci Rasea watershed. It was shown from land clearing for settlement which mostly came from scrub areas. In addition, the decreasing of forest and shrub area was caused by the changes of forest and scrub to cropland.

The spatial pattern cropland HRU based on land cover classification data, had a lot of changes in the upstream, midstream and downstream of the watershed due to changes in land cover during 1997-2009. Some plantation HRU found in the middle and downstream of the watershed. The changes of plantation HRU during 1997-2009 occurred in the middle and downstream of the watershed. Its were caused due to there are many land cover changes for the plantation which occurred during 1997-2009 at that place.

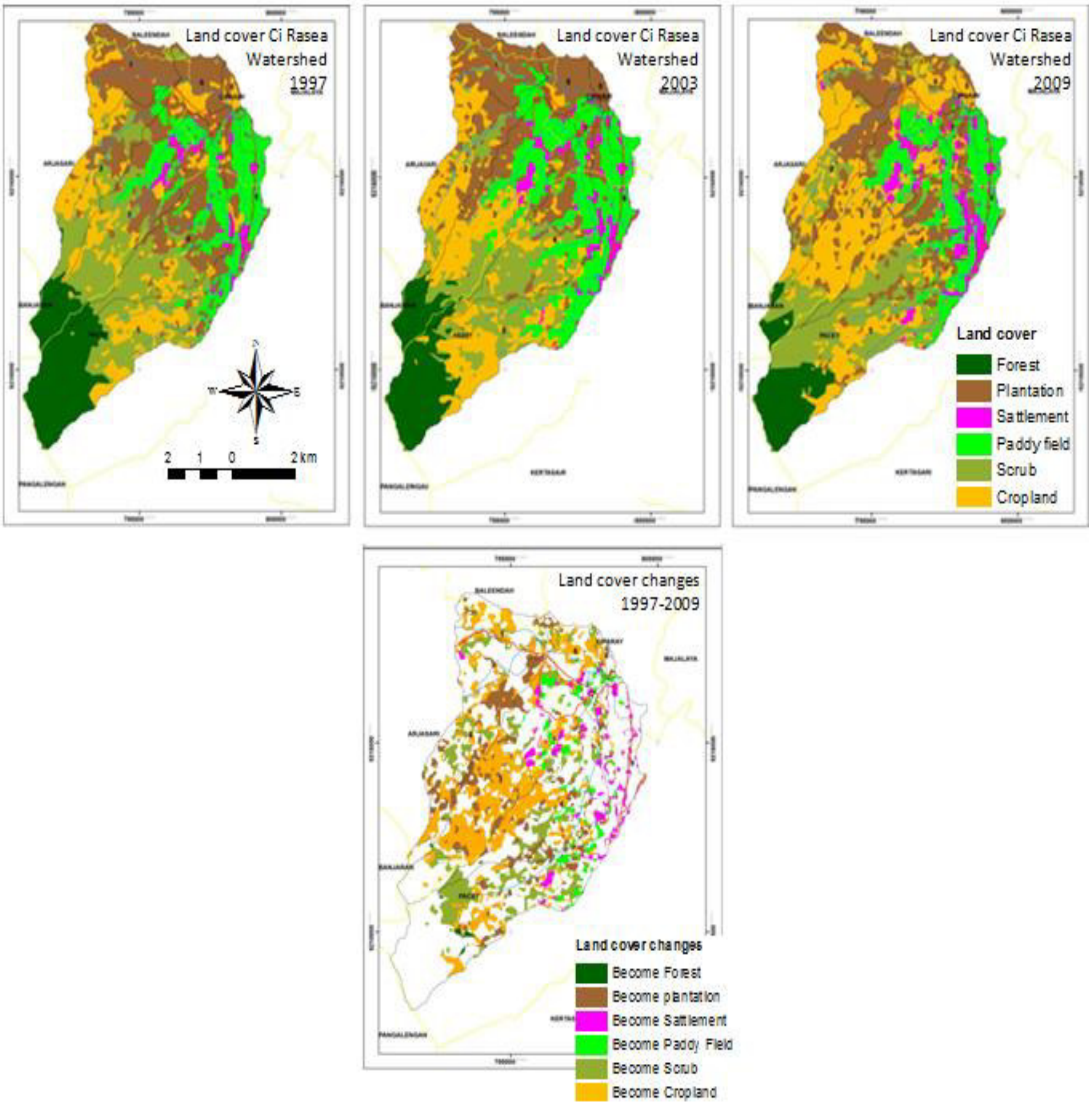

Figure 3-1: The classification results for landcover of Ci Rasea watershed in 1997, 2003, and 2009 (above) and landcover changes during 1997-2009 (below)

Tabel 3-1: Landcover Change in DAS Cirasea 1997, 2003, and 2009

Landcover classes	**Areas (Ha)**			**Landcover changes**					
	1997	**2003**	**2009**	**1997-2003**		**2003-2009**		**1997-2009**	
				Ha	**%**	**Ha**	**%**	**Ha**	**%**
Forest	923	763	719	-160	-17	-44	-6	-203	-22
Plantation	1817	1518	1427	-299	-16	-91	-6	-390	-21
Sattlement	195	291	343	96	49	52	18	148	76
Paddy field	980	1358	906	378	39	-452	-33	-75	-8
Scrub	1522	1201	1206	-321	-21	5	0	-316	-21
Cropland	1173	1479	2010	306	26	530	36	837	71

Spatial patterns of HRU of forest located in the upstream watershed. During 1997-2009 were found that many changes of forest HRU due to land cover changes. Spatial patterns of paddy field HRU occurred in the middle and upstream of watershed during 1997-2009 due to land cover change. The spatial patterns of HRU for scrub were found widely in the middle and upper of watersheds. During 1997-2009 found many HRU of scrub changed because of changes in land cover. The spatial pattern of settlement HRU mostly found in downstream of watershed and also changes during 1997-2009 due to land cover changes in that place.

Cluster analysis was obtained 9 sub regions Ci Rasea watershed (Figure 3-2). The number of HRU, HRU dominant and the areas can be seen in Table 3-2, which showed many changes of HRU pattern during 1997 to 2009 in each sub region which were associated with land cover changes. The majority of spatial pattern which happen during 1997 to 2009 for each sub region are clustered. The changing of the spatial pattern cluster at random only happens in 2009 for sub region 3, 4 and 6. The changing of spatial patterns also caused the changes of the size and dominance HRU. During 1997-2009, the HRU changes, mostly occurred at sub region 3 due to the increasing of cropland. In contrary the few changes of HRU occurred in sub region 8 due to only few landcover changes in that area.

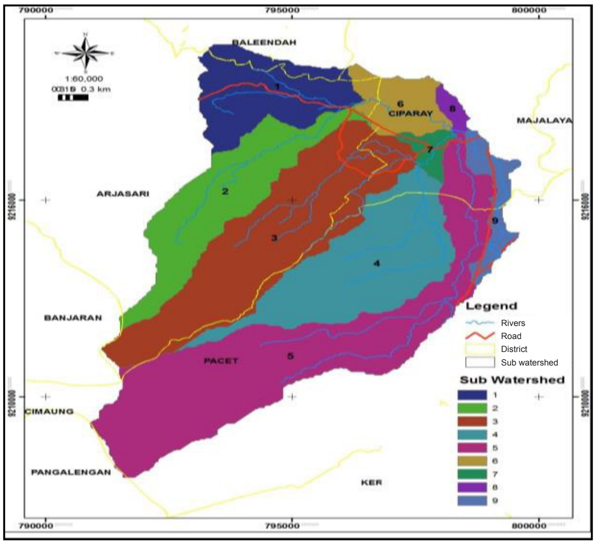

Figure 3-2: Sub region in Ci Rasea watershed based on cluster analysis

Table 3-2: Numbers of HRU, HRU dominant, area of HRU and spatial pattern from each sub region during 1997-2009 in Ci Rasea watershed

Sub region	HRU Dominant (Landcover/soil/slope)			Areas of HRU Dominant (Ha)			Spatial Pattern		
	1997	2003	2009	1997	2003	2009	1997	2003	2209
1	Plantation/ C/15-25	Plantation/ C/15-25	Plantation/ C/8-15	120.7	127.3	104.4	Cluster	Cluster	Cluster
2	Cropland/ C/8-15	Cropland/ C/8-15	Cropland/C /8-15	142.4	135.1	140.8	Cluster	Cluster	Cluster
3	Plantation/ C/15-25	Paddy field/C/0-8	Cropland/C /15-25	99.6	115.5	129.6	Cluster	Cluster	Random
4	Scrub/C/2 5-40	Scrub/C/ 25-40	Scrub/C/1 5-25	101.4	130.1	91.98	Cluster	Cluster	Random
5	Forest/CL/ >40	Forest/CL/ >40	Forest/CL/ >40	255	171.3	171.4	Cluster	Cluster	Cluster
6	Plantation/ C/8-15	Plantation/ C/15-25	Cropland/C /0-8	47.83	52.44	53.52	Cluster	Cluster	Random
7	Plantation/ LS/0-8	Paddy field/LS/ 0-8	Plantation/ LS/0-8	20.8	30.26	15.9	Cluster	Cluster	Cluster
8	Cropland/ SIC/8-15	Plantation/ LS/25-40	Plantation/ LS/ 25-40	6.73	8.44	7.36	Cluster	Cluster	Cluster
9	Paddy field/SIC/0 -8	Paddy field/SIC/ 0-8	Paddy field/SIC/0 -8	125.7	118.7	117.5	Cluster	Cluster	Cluster
Number of HRU				269	266	288			

Surface run off (QSurf) which was obtained each sub region of the watershed using SWAT models were obtained could be seen in Table 3-3. The accumulation of runoff, mostly occurred in sub region 2 which has dominated HRU cropland/C/8-15. It was meant the dominant land cover in that sub region was cropland with type of soil was clay and slightly tilted slopes. Furthermore, sub region of the watershed, which resulted lowest accumulation of runoff was subregion 7 due to the land cover of sub region 7 was plantation and paddy field, with flat areas and type of soil was sandy loam.

The increasing of surface runoff in linearly was happening in sub region 2, 3 and 9 due to the addition of accumulated surface runoff. Otherwise the increasing of surface runoff in SubDAS 1, 4, 5, 6, 7 and 8 were fluctuated due to the decrease and increase of surface runoff accumulation in that sub region during 1997-2009. The changes of surface runoff accumulation were happening due to the changes of HRU each sub region of the watershed. Therefore, the HRU in each sub region affected the accumulation of runoff.

The dominant HRU which was causing a lot of surface runoff accumulation were cropland with type of soil were clay and slope slightly tilted. Furthermore, HRU which caused a little accumulation of surface runoff were plantation with type of soil were clay and flat area. This research found that to reduce the accumulation of surface runoff in the Ci Rasea watershed, which has slightly titled of the slopes and clay soil could be used the plantation as land cover.

The flow rate each sub region can be seen in Table 3-4. The table showed that the greater distance of sub region from the outlet results the smaller flows. Thus, the sub region, which has the smallest flow was sub region 1. In contrary the closer distance of the sub region to the outlet, then the flow becomes greater. This was occurring in sub region 9 which has HRU mostly consists of paddy fields and settlements. Table 3-4 described the changes of flow were linear and increasing during 1997 to 2009 in sub region 2, 3, 6, 7, 8 and 9. Furthermore, on sub region 1, 4 and 5 the changes of flow were fluctuating during that period due to the changes of HRU on each sub region.

Table 3-3: The accumulation of runoff (Qsurf) during 1997-2009 in each sub region

Sub region	Surface runoff (mm)			Surface runoff changes (mm)		
	1997	2003	2009	1997-2003	2003-2009	1997-2009
1	32.2	31.8	32.5	-0.31	0.61	0.30
2	34.2	35.1	35.2	0.86	0.10	0.97
3	30.8	31.7	33.6	0.88	1.93	2.81
4	30.1	29.8	30.3	-0.25	0.48	0.24
5	29.4	30.5	29.9	1.10	-0.57	0.53
6	31.7	31.4	32.6	-0.26	1.20	0.94
7	19.4	20.0	19.7	0.58	-0.27	0.31
8	24.1	22.1	25.0	-1.94	2.85	0.91
9	28.8	29.1	29.3	0.33	0.22	0.55
Mean	29.0	29.1	29.8	0.1	0.7	0.8

Table 3-4: Changes of flow discharge during 1997-2009 in each sub region of watershed

Sub region	**Flow discharges (m3/s)**			**Flow discharge changes (m3/s)**		
	1997	**2003**	**2009**	**1997-2003**	**2003-2009**	**1997-2009**
1	2.5	2.5	2.5	-0.02	0.04	0.02
2	3.3	3.4	3.4	0.08	0.01	0.09
3	5.3	5.5	5.8	0.15	0.31	0.45
4	3.9	3.9	3.9	-0.03	0.06	0.03
5	6.7	6.9	6.8	0.24	-0.12	0.11
6	6.9	7.0	7.1	0.05	0.09	0.14
7	9.5	9.6	10.0	0.12	0.36	0.48
8	16.5	16.7	17.2	0.16	0.47	0.63
9	24.0	24.4	24.7	0.40	0.35	0.75
Mean	8.7	8.9	9.0	0.1	0.2	0.3

SWAT model simulations were carried out using rainfall data from January to April period of 2009 from Ciparay station. Therefore, the calibration and validation of the model are done by using flow data from fields in the same period, ie from January to April 2009 recorded by the post-Cengkrong Cirasea hydrology. Calibration and validation of the model is done by comparing the flow field in the same year with flow resulted from SWAT model. The files contained on SWATOutput.mdb.

By using 121 numbers of samples, the efficient model of Nash-Sutcliffe (NS) for flow rate model resulted 0.7 and accurate 0.7. It means the model satisfactory for analysis and has a fairly high correlation. The t-student test resulted p = 0.06 at a significance level of 5% with correlation 0. 84. Therefore, the null hypothesis (Ho) accepted or there are not real differences between flows model and flows from field measurement. The research also found that that flows model of sub watershed, which close to main channel has high accuracy, while the flow model of subs watershed which was far away from main channel has a low accuracy. Based on Table 3-2, 3-3 and 3.4 can be seen that the changing of HRU spatial pattern in 1997 to 2009 from each sub region affect surface runoff and flow discharge significantly.

4 CONCLUSION

During 1997-2009, the majority of HRU spatial pattern at Ci Rasea watershed were clustered. Analysis of Hydrologic Response Unit (HRU) in Ci Rasea watershed during 1997-2009 showed the landcover affected by the spatial pattern of HRU temporally. This is indicated by the changes of numbers area and spatial pattern of each HRU. The changes of HRU as spatial caused by how much detail the spatial resolution of landcover which were used.

During 1997-2009 the changes of HRU spatial pattern effected surface runoff accumulation and flow discharges. Accumulation of surface runoff in Ci Rasea watershed can be reduced by making some area become plantation in clay soil and slightly tilted slope areas and areas which have a sandy loam soil and flat slope can be used for paddy fields.

HRU which was causing large amount accumulation of flows in the Ci Rasea watershed was HRU plantation with clay soil and slightly tilted slopes. Furthermore, HRU, which was causing small amount accumulation of flows in the Ci Rasea watershed, was HRU paddy field with sandy loam soil type and flat slope.

Beside influenced by HRU, amount of flow discharges also influence with distance of sub watershed with the outlet. Accuracy of flow models with this HRU was 70%. It was meant that the model can better simulate flows of the Ci Rasea watershed.

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