Spatial Modeling of Sediment Transport over the Upper Citarum Catchment

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Abstract. This paper discusses set up of a spatial model applied in Geographic Information System (GIS) environment for predicting annual erosion rate and sediment yield of a watershed. The study area is situated in the Upper Citarum Catchment of West Java. Annual sediment yield is considered as product of erosion rate and sediment delivery ratio to be modelled under similar modeling tool. Sediment delivery ratio is estimated on the basis of sediment resident time. The modeling concept is based on the calculation of water flow velocity through sub-catchment surface, which is controlled by topography, rainfall, soil characteristics and various types of land use. Relating velocity to known distance across digital elevation model, sediment resident time can be estimated. Data from relevance authorities are used. Bearing in mind limited knowledge of some governing factors due to lack of observation, the result has shown the potential of GIS for spatially modeling regional sediment transport. Validation of model result is carried out by evaluating measured and computed total sediment yield at the main outlet. Computed total sediment yields for 1994 and 2001 are found to be 1.96×10^6 and 2.10×10^6tons/year. They deviate roughly 54 and 8% with respect to those measured in the field. Model response due to land use change observed in 2001 and 1994 is also recognised. Under presumably constant rainfall depth, an increase of overall average annual erosion rate of 11% resulted in an increase of overall average sediment yield of 7%.

Keywords: *Citarum; erosion rate; sediment delivery ratio; sediment yield; GIS.*

1 Introduction

Transport of sediment by water is one among natural processes that occurs over a river basin. Overland movement of sediment particles can be seen as a stabilisation process of basin elevation to reach equilibrium topography. From another point of view, one might argue that detachment of sediment particle from river basin surface and the corresponding transport through hillslope and river network are potential natural hazard. It may lead to loss of organic material and nutrients, reduction of crop productivity and downstream water

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quality degradation 1. In this particular case, the study of sediment transport is substantial in prioritising effort for watershed management. Scientific support of a certain level is therefore essential.

Understanding a complex system, such as a river basin, has challenged modellers to develop an optimised approach in order to meet accuracy requirement and model simplicity. The growth of spatial modeling using Geographic Information System (GIS) provides an effective tool for handling space-related processes including transport of sediment. Spatial concept to be applied in sediment transport study considers distance as an important control parameter to represent movement process of sediment particle by water. Distance will be related to water velocity and travel time. Recognising water velocity over various types of surface will lead to the estimation of travel time, in which one can empirically calculate the amount of sediment deposited and those further transported through catchment outlet.

This paper discusses the application of existing empirical approaches for predicting potential distribution of erosion and export of sediment from a river basin. Theory behind the approach has been proposed by 2 and developed further by 1. The specific objectives of this study are (1) to model spatial distribution of erosion rate, (2) to estimate the amount of sediment yield and (3) to evaluate the effect of land use change to the gross erosion rate as well as sediment yield from the system being studied. Accordingly, maps showing sources of erosion over the entire domain will be shown. In addition to that, spatial distribution of sediment yield from all sub-catchments will also be given. The idea of using GIS for watershed studies has been initiated since the growth of spatial computation science. In this paper latest development in modeling of erosional behaviour of a watershed is documented.

2 Methods

2.1 Investigation domain

The investigation domain is situated in the Upper Citarum Catchment (UCC). The term ‘Upper’ here is restricted to that part of Citarum drainage basin whose tributaries and the corresponding catchment outlet are discharged to Saguling reservoir (Fig. 1). It covers an approximated area of 1771km^2 3. Citarum Catchment is one among the biggest watershed in the western part of Java. For managerial purposes the UCC is divided into five catchment sub-divisions being Cikapundung, Citarik, Cisarea, Cisangkuy and Ciwidey. Monthly rainfall depth recorded in 2001 varies from 45 to 352mm with accumulated annual value of up to 2200mm. The topography is dominated by mountainous landscape along the catchment boundary with flood plain covering the centre of the basin. Recent thematic mapping confirms agricultural zone as the predominant type of land use.

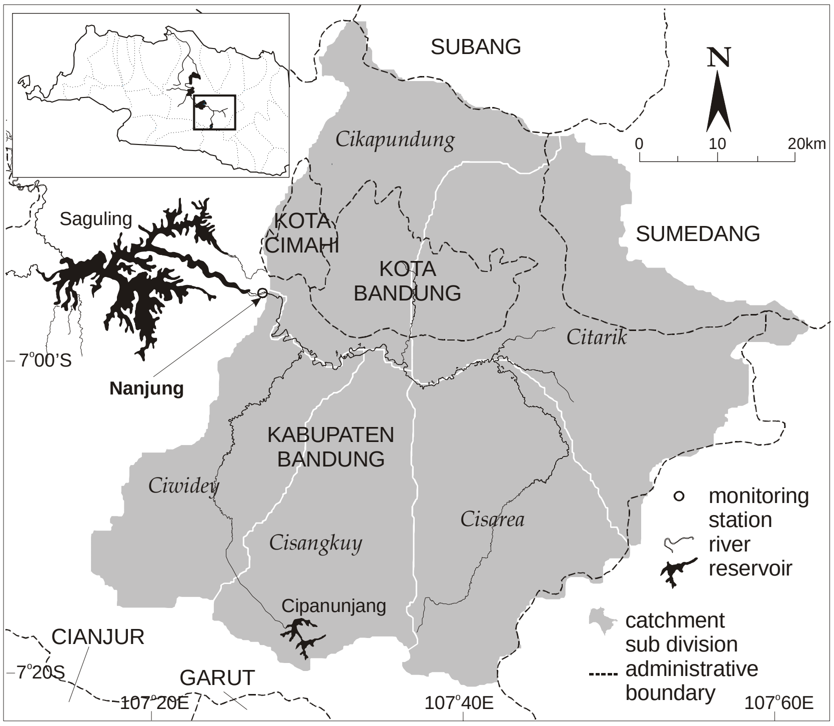


Figure 1 Investigation domain.

2.2 Erosion Rate and Sediment Delivery Ratio Models

Sediment transport over a catchment is usually observed as annual amount of material discharged through a catchment outlet. The discharged sediment in this particular location is resulted from erosion and delivery processes across a catchment. Considering a catchment system, the amount of annually eroded sediment is termed as erosion rate (E) and expressed in ton/km^2/year. E is regarded as gross amount of eroded sediment. It is mainly governed by (i) catchment geometry (e.g. slope and surface roughness), (ii) characteristics of surface sediment (e.g. grain size and texture) and (iii) hydrological forcing (i.e. rainfall). Along the way through catchment hillslope, some of the transported sediment will be eventually deposited, whereas some other will be routed further through channel network and eventually exported through catchment outlet.

The exported sediment from a catchment or sediment yield (Y) is therefore much lower than those eroded from the entire catchment. An efficiency factor is then introduced to relate E and Y as:

$$SDR = \frac{Y}{E} \tag{1}$$

with SDR = sediment delivery ratio. SDR can be interpreted as physical response of a catchment for transporting sediment from sources of erosion to the corresponding network channel. It reflects several controlling factors including travel distance, route geometry and surface characteristics. SDR has values between 0 and 1 and is commonly inversely proportional to catchment area at constant rate of αA^{β}. α and β represent processes of sediment detachment due to rain, degree of landscape exposure and topographic condition as well as transport capacity across catchment surface and drainage network.

The model being investigated in this study considers regional erosion rate (E) and SDR as landscape-dependent parameters to estimate sediment yield (Y). Accordingly, the discussion will be mainly focused on the estimation of spatially distributed erosion rate and SDR. In case of erosion rate estimation, an empirical approach proposed by 4 will be applied. For SDR modeling, recent method developed by 1 will be used. The models only estimate sheet and rill erosion and neglect either gully or bank erosion. The estimated sediment yield will be given in ton/km^2/year being the product of E and SDR.

2.2.1 Erosion rate model

Universal Soil Loss Equation (USLE) proposed by 4 is used to model an estimated value of erosion rate. The erosion rate E is empirically calculated as function of slope index (L_S), land use (C), erodibility (K) and erosivity (R):

$$E = L_S CKR \tag{2}$$

Slope index L_S is obtained from a Digital Elevation Model (DEM) for the given domain as 4:

$$L_S = \left(\frac{L}{k}\right)^b \left(k_1 \sin^2 s + k_2 \sin s + k_3\right) \tag{3}$$

with,

$b = 0.2$ for $0 \le s < 1$
$b = 0.3$ for $1 \le s < 3$
$b = 0.4$ for $3 \le s < 4.5$
$b = 0.5$ for $s \ge 4.5$

where L = length of sloping profile having value of higher than 122m 5, b = slope index and s = percent slope, in which $k = 22.1$, $k_1 = 65.41$, $k_2 = 4.56$ and $k_3 = 0.065$ being empirical constants.

Type of land use (C) is obtained from a look-up table (Table 1). Land use is grouped according to its exposure. In this manner, water bodies (e.g.: ponds, lake, river, etc.) is categorised as the most protected land use and mining zone as the most exposed land use. The rests fall between those two extremes.

Table 1 Land use value 6.

Land use type	C
Rivers / ponds / lakes	0.0001
Industrial zone	0.0005
Residential	0.0007
Aquatic vegetation / wetland	0.001
Forest	0.002
Shrub, pastures, park	0.003
Farm, garden, dry field	0.005
Open land	0.4
Mining zone	0.7

Erodibility (K) represents the mobility of sediment particle due to detachment by kinetic energy from rainfall and transport by surface run off. It can be seen as sediment resistance to movement, which is governed by soil texture, aggregate stability, infiltration capacity as well as organic and chemical contents of soil. A look-up table for K is given in Table 2.

Table 2 Erodibility 7 13.

Soil type	*K*	Code
Alluvial, planosol, gray hydromorf, lateric	0.20	3
Latosol	0.23	1
Mediteran	0.24	2
Andosol, grumosol, podsol, podsolic	0.26	0
Regosol, litosol, organosol, renzina	0.31	2

Erosivity R is an index representing external forcing capacity generated by rainfall to detach sediment particles from soil surface. R is expressed as function of rainfall depth P 8:

$$R = 2.21P^{1.36} \tag{4}$$

with P = monthly rainfall depth.

2.2.2 Sediment Delivery Ratio (*SDR*) model

Empirical *SDR* model to be applied in this study is developed by 2. The modeling concept is based on the sub-division of a catchment into two-storage element being (i) hillslope storage and (ii) network channel storage. Schematic visualisation of linear relation between erosion rate E and sediment yield Y is shown in Fig. 2. Time-dependent sediment export from erosional area to the channel storage is expressed as $y_h(t)$. Linear relation between $y_h(t)$ and the corresponding hillslope storage capacity is then expressed as:

$$\frac{S_h(t)}{t_h} = E - y_h(t) \tag{5}$$

with $S_h(t)$ = amount of sediment storage in the hillslope element and t_h = sediment resident time in the hillslope storage. Linear relation between sediment yield Y with supplies from network channel storage is expressed as:

$$\frac{S_n(t)}{t_n} = y_h(t) - Y \tag{6}$$

with $S_n(t)$ = amount of sediment storage in the network channel element and t_n = sediment resident time in the network channel storage.

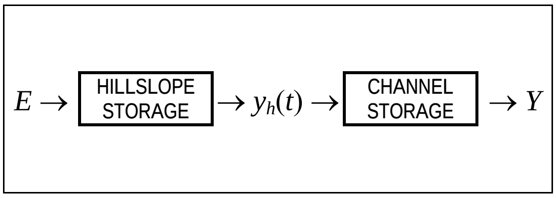


Figure 2 Schematic visualisation to relate Y and E.

Analytical solution of eqs. (5) and (6) is derived by 2 being power law function of sediment resident time (t_h and t_n) and effective rainfall duration (t_{er}):

$$SDR = \frac{t_n}{t_n - t_h}\left(1 - e^{\left(-t_{er}/t_n\right)}\right) - \frac{t_n}{t_n - t_h}\left(1 - e^{\left(t_{er}/t_h\right)}\right) \quad \text{for } t_n \neq t_h \tag{6a}$$

$$SDR = \frac{1}{2}\left(\frac{t_{er}^2}{t_n^2}\right) + \frac{1}{3}\left(\frac{t_{er}^3}{t_n^3}\right) + \ldots \quad \text{for } t_n = t_h \tag{6b}$$

with $SDR = Y/E$. Sediment resident time either in the hillslope element or network channel becomes governing factor to express catchment capacity to transport sediment. Since sediment particle is transported by water flow, resident time is then estimated on the basis of travel time of water as:

$$t_h = t_{hw} F_h \tag{7a}$$

$$t_n = t_{nw} F_n \tag{7b}$$

with t_{hw} = travel time across hillslope, t_{nw} = travel time across network channel, whereas F_h and F_n are the multitude function being:

$$F_h = e^{(\gamma_h w_s)} \tag{8a}$$

$$F_n = e^{(\gamma_n w_s)} \tag{8b}$$

with w_s = sediment settling velocity in the water column, whereas γ_h and γ_n, are inversely proportional factors related to flow depth, in which $\gamma_h = h_h^{-1}$ and $\gamma_n = h_n^{-1}$, with h_h and h_n are flow depths across hillslope and network channel, respectively. Sediment settling velocity is estimated using:

$$w_s = \left(\frac{4 \rho_s g d}{3 \rho C_D R_{ep}} \right)^{\frac{1}{2}} \tag{9}$$

with ρ_s = sediment density, ρ = water density, g = acceleration due to gravity, d = grain size, $R_{ep} = w_s d / \nu$ being Reynolds number for the given settling velocity and sediment grain size, ν = kinematic viscosity of water and C_D = drag coefficient:

$$C_D = \frac{24}{R_{ep}} \left(1 + 0.15 R_{ep}{}^{0.687} \right) \tag{10}$$

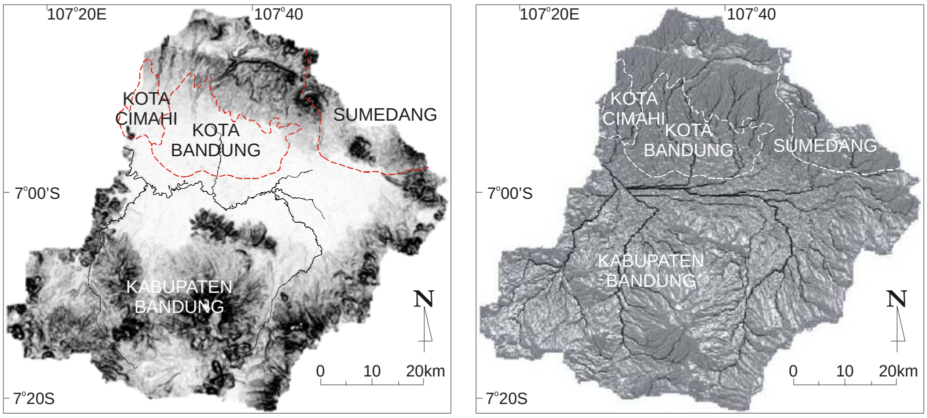
2.3 Implementation

2.3.1 Model set up

Steps for implementing erosion rate and *SDR* models under GIS environment are sequentially carried out as follows:

1. defining spatial unit on to which the estimation of sediment yield is done; and
2. calculating average travel time of water flow across hillslope and channel network within a spatial unit.

For the first step of model set up, the entire domain is geometrically represented by 90m resolution DEM. The DEM in question is extracted from Shuttle Radar Topographic Mission (SRTM) data 9. The DEM is then derived into slope and consecutively to drainage network elements with the corresponding delineated sub-catchment boundaries (Fig. 3). For this particular purpose a method proposed by 10 is applied. Each delineated sub-catchment is termed as spatial unit. A spatial unit, hence, consists of a number of grid cells. Calculation of erosion rate is carried out within each 90×90m^2 grid cell of the DEM. A spatial unit becomes the basis of *SDR* and sediment yield calculations. In the domain being investigated, there are about 4100 spatial units, each has an approximate area of ranging between 8×10^{-3} and 70km^2. ESRI Arc/Info 11 software is used as spatial modeling tool.



(a) Slope map (b) Drainage network

Figure 3 Derivatives of UCC's DEM from SRTM data.

For the second step of model set up, average travel time of water flow (from source of erosion to catchment outlet) through flow path within a spatial unit is calculated. The calculation considers those occur through every grid cell in the hillslope element (t_{hw}) as well as in the network channel element (t_{nw}). In the hillslope, the travel velocity is estimated as:

$$V_h = \frac{(i_e L)^{0.4} s^{0.3}}{n^{0.6}} \tag{11}$$

with V_h = hillslope velocity, i_e = rainfall excess rate, L = travel distance along the flow path, s = decimal slope and n = Manning's roughness coefficient. Rainfall excess rate i_e varies within different types of land use and is estimated using:

$$i_e = \frac{P_e}{t_r} \tag{12}$$

with t_r = average rainfall duration and P_e = excess of rainfall depth:

$$P_e = \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{13}$$

with P = rainfall depth and S = storage term which is expressed as function of land use variation:

$$S = \frac{254}{CN}100 - 254 \tag{14}$$

with CN = curve number representing land use variability and is obtained as area-weighted average of land use type:

$$CN = \frac{\sum_{i=1}^{m} CN_i A_i}{\sum_{i=1}^{m} A_i} \tag{15}$$

with i = sub-area (within a spatial unit) having a particular type of land use, m = number of sub areas, CN_i = number representing storage term and A_i = area. A look-up table for CN is given in Table 3. The values 0 to 3 in Table 3 correspond to soil characteristic codes and represent storage capacity according to specific type of soil as given in Table 2.

Table 3 *CN* (contextually concised from 12).

Types of Land Use	CN			
	0	**1**	**2**	**3**
Residential	49	69	79	84
Shrub, pastures, park	48	67	77	83
Forest	30	55	70	77
Farm, garden, dry field	72	81	88	81
Aquatic vegetation / wetland	66	74	80	82
River / pond / lake	98	98	98	98

Manning's roughness coefficient n is given to eq. 11 according to generic type of land use and percentage of vegetation cover (C_v) as shown in Table 4.

Table 4 Manning's roughness coefficient 1.

Land Use	Vegetation Cover (C_v) in %		
	C_v<30	30<C_v<70	C_v>70
Pasture	0.15	0.4	0.6
Crop	0.15	0.25	0.4
Forest	0.2	0.6	0.8
Built-up areas	0.1	0.3	0.5
Wetland and ponds	0.125	0.125	0.125

In the network channel the velocity of flow is calculated using:

$$V_n = as^{0.5} \tag{16}$$

with V_n = flow velocity in the network channel, s = decimal slope and a = coefficient representing streambed roughness. Values for a are given in Table 5.

Table 5 Channel roughness parameter 1.

Channel section	Upstream area (Ha)	*a*
Concentrated shallow flow	1.8–18	4
Intermittent stream	18–360	4.5
Permanent stream	>360	5

Knowing V respectively from eqs. 11 or 16, the travel time (t) across each grid cell in the DEM can be calculated as:

$$t = \frac{D}{V} \tag{17}$$

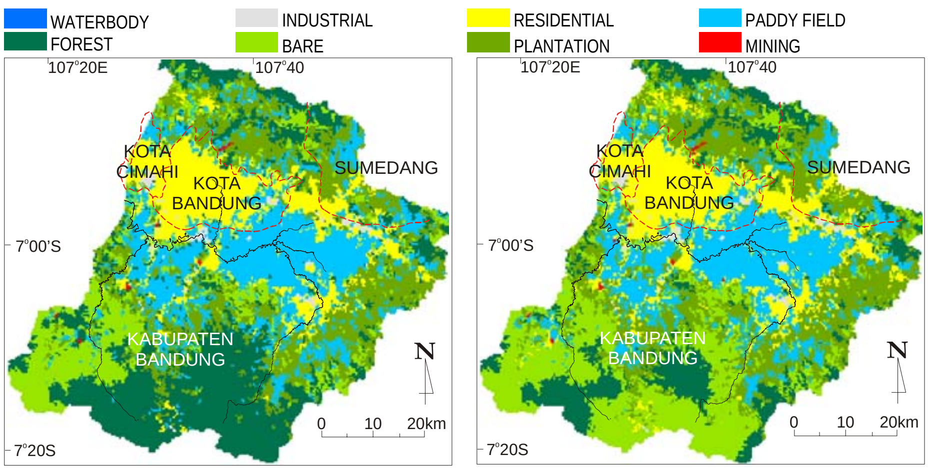
with D = travel distance on the DEM, where D equals to grid cell size for orthogonal flow or $D\sqrt{2}$ for diagonal flow.

2.3.2 Input parameters

Since information regarding sediment size distribution is not available, representative sediment type is assumed to be silt having median diameter of 80µm. It gives an approximated settling velocity of 0.09m/s. Flow depth to be used in eq. 8 is assumed to be 0.2cm for hillslope and 1m for channel network. Furthermore, two governing geometric parameters are derived from SRTM DEM. They comprise slope (including slope index) and length of water flow (across hillslope and network channel) (see Fig. 2) on to which the entire calculations are applied. SRTM data provides relatively accurate and up-to-date DEM with acceptably uniform distribution and spatial resolution. Further details regarding this can be seen in 9.

In addition to that, spatial distribution of soil characteristics and land use types are taken into account. In case of land use, two historical thematic maps from 1994 and 2001 are considered (Fig. 4). From later map it is found that agricultural zone is the typical type of land use. It covers an approximate area of 1587km^2 and corresponds to 66% of the entire UCC. The second most dominant type of land use is primary and secondary forest. It covers an approximate area of 509km^2 or 21% of the entire UCC. Within seven years the UCC undergoes severe deforestation and significant extension of agricultural and residential zones. Further detail regarding this is shown in Table 6.

We have been challenged by limited knowledge in estimating average rainfall duration (t_r) and effective rainfall duration (t_{er}) due to lack of measurement data. For the modeling purpose, we propose to assume that both average and effective rainfall duration is directly proportional to mean annual rainfall (MAR). An investigation of relationship between MAR with the corresponding rainfall duration and effective rainfall has been documented in 1. It is shown that within a range of MAR from 250 to 1500mm a range of average rainfall duration and effective rainfall duration from 7.5 to 25 hours is observed. Furthermore, we assume that erosion occurs during the entire effective rainfall duration. Rainfall data is obtained from Meteorology and Geophysics Agency (*Badan Meteorologi dan Geofisika* - BMG). It consists of five representative measuring stations from all upper catchment sub-divisions and covers only measurement from 2001.



(a) 1994 (b) 2001

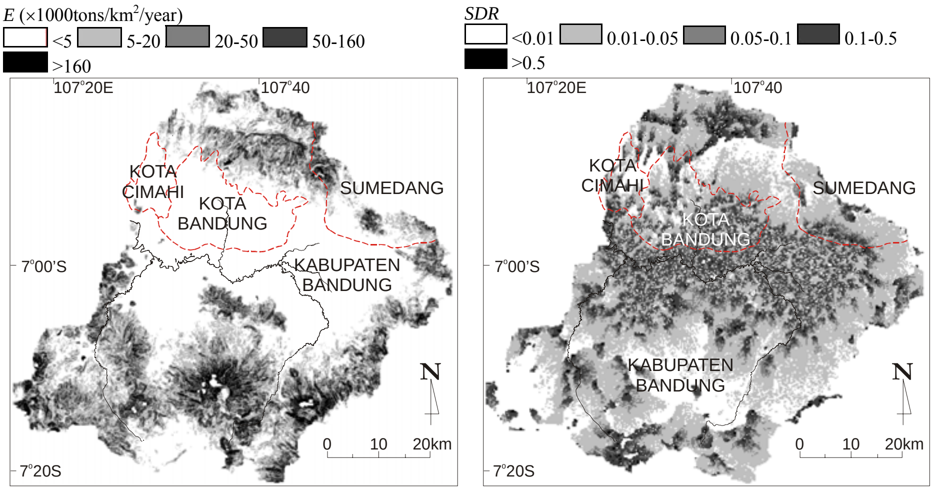
Figure 4 Land use maps across Upper Citarum Catchment.

Table 6 List of major types of land use across UCC.

Types of Land Use	1994		2001		Change	
	km^2	%	km^2	%	km^2	%
Forest	1211.7	46.3	509.2	21.2	-702.5	-58.0
Agriculture	1125.0	43.0	1587.4	66.1	462.4	41.1
Residential	279.3	10.7	303.5	12.6	24.2	8.7

3 Results

For the sake of compactness of this paper, only modeling results from condition in 2001 are shown here. Fig. 5 shows spatially distributed erosion rate and *SDR*. It can be seen that higher erosion rates are concentrated in the mountainous part of the UCC (Fig. 5a), whereas higher *SDR*s are seen more in the central part of the UCC (Fig. 5b). Our model shows that in 2001 erosion rate within each spatial unit (area specific) is between a range of 10.9 and 7.3×10^6tons/km^2/year with average value of 25131tons/km^2/year. Area specific *SDR* is between 2×10^{-4} and 0.96 with average value of 0.071 which remains effectively constant in 1994 and 2001 (*SDR* increase is only within the order of 10^{-6}). This is due to the use of constant hydrological forcing and geometric representation of catchment landscape.



(a) *E* (b) *SDR*

Figure 5 Spatially distributed erosion rate and sediment delivery ratio.

Relationship between *SDR* and sub-catchment area (*A*) shows that there is a decrease of *SDR* with increasing *A* (Fig. 6), thus, confirming empirical trend of *SDR* 14, 15, 16. Relatively gently sloping trend of *SDR* with increasing *A* as shown by 14, 15 and 16 is due to the derivation of such empirical *SDR-A* equation using large number of watershed. In our case, the modeling comprises only one catchment area with relatively small size. Applying simple regression analysis to the 2001 modeling results gives:

$$\log(SDR) = -0.386\log(A) - 1.0213 \tag{18}$$

Eq. 18 gives r^2=0.70.

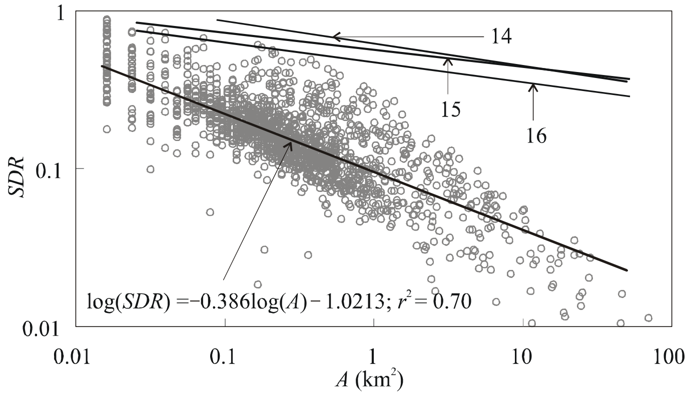


Figure 6 *SDR* vs. sub-catchment area (*A*).

Continuous monitoring of sediment supply from the UCC in terms of sediment discharge has been made by Water Resources Research and Development Centre of the Office of Public Works of West Java Province (*Pusat Penelitian dan Pengembangan Sumberdaya Air*, *Kantor Pekerjaan Umum Propinsi Jawa Barat* - Pusair SDA PU Jabar). The measuring station is located at Nanjung representing the main outlet of the catchment being studied (see Fig. 1). Total annual sediment yield being the accumulation of area specific sediment yields measured in 1993 and 2003 are respectively 1.20×10^6 and 2.15×10^6tons/year. According to measurement data (1976, 1981, 1993, 2003 and 2004), there is a significant increase of total sediment yield.

Comparison between measured and computed total sediment yield is made (Fig. 7). The computed values deviate approximately 54 and 8% with respect to roughly predicted trend of measured total sediment yield. Higher discrepancy of total sediment yield in 1994 is due to presumably constant rainfall depth for the computed years (1994 and 2001). We have decided to use rainfall depth data measured in 2001 to be also used to model the condition in 1994. This is due to lack of rainfall depth measurement in 1994. However, the deviation is considered to be acceptable since the computed value still within the same order of those measured in the field. Comparable agreement between measured and computed total sediment yield of ranging from -24 to 10% is reported by 17.

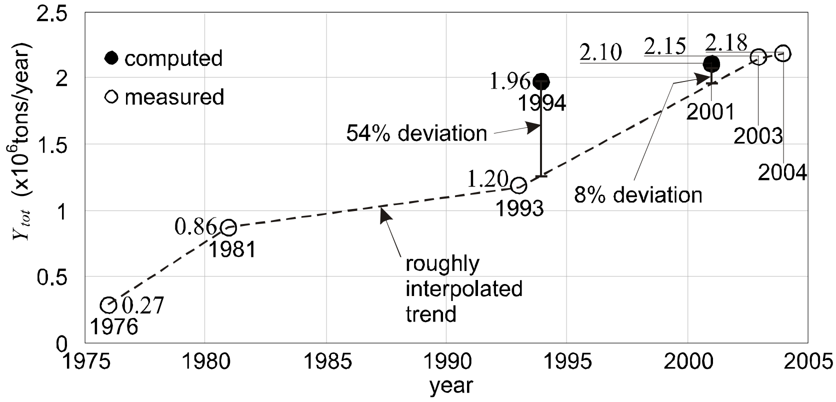
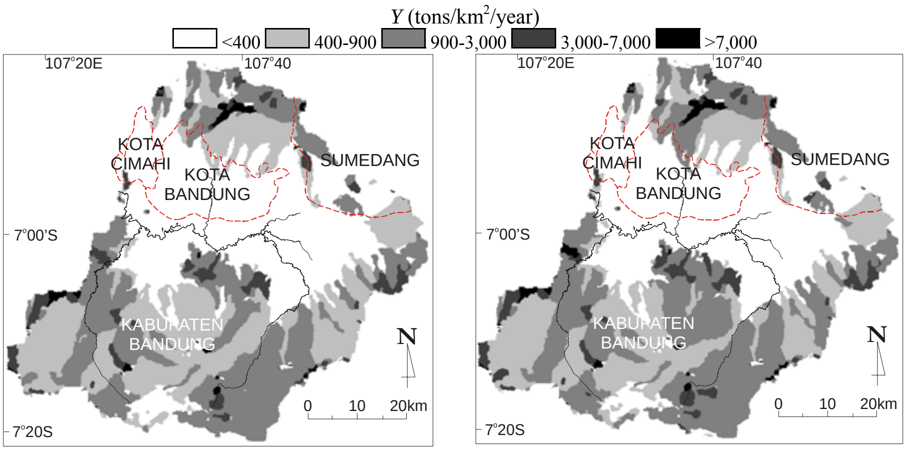


Figure 7 Comparison between measured and computed total sediment yield.

Discrepancy between measured and computed total sediment yield can be resulted from many sources. Firstly, the measured value might content uncertainty of a certain level. Secondly, limited capability of the model and the corresponding empirical formulae for simulating complex natural processes. Thirdly, the quality of data for setting up the model. For the case of this study, the most detectable factor is obviously originated from the inaccuracy of erosion rate and *SDR* estimation. This is due to generalisation of geometric and physical representation of catchment landscape, the use of uniform size of sediment and limited knowledge of detailed rainfall behaviour over the UCC. Further improvement should therefore be focused on attaining knowledge of the latter two parameters. However, since computed sediment yield is within the same order with those measured on the field, the overall results are proposed to give preliminary depiction of sediment transport process across the UCC.

Fig. 8 shows spatial distribution of sediment yield computed for 1994 and 2001. Above average sediment yield (900-7000tons/km^2/year) is found at the northern part of Cikapundung catchment sub-division, the south-western part of Ciwidey catchment sub-division, the southern to middle parts of Cisangkuy catchment sub-division, the southern to western part of Cisarea catchment sub-division and the western part of Citarik catchment sub-division. Higher sediment yield (3000-7000tons/km^2/year) is found at the northern part of Cisangkuy and Cisarea catchment sub-divisions. The highest sediment yield (>7000tons/km^2/year) is found at the northern part of Cikapundung catchment sub-division and the western part of Ciwidey catchment sub-division.



(a) 1994 (b) 2001

Figure 8 Area (i.e. sub-catchment) specific sediment yield (*Y*).

The relatively gently sloping topography across the central UCC produces relatively low sediment yield. Within seven years an increase of sediment yield is observed at the western part of Ciwidey as well as the northern part of Cisangkuy and Cisarea catchment sub-divisions, just south of Bandung Municipal. An increase of sediment yield is also observed at the middle part of Cikapundung catchment sub-division, just north of Bandung Municipal. The other parts of UCC produce relatively constant amount of sediment yield. One might relate the trend of increasing sediment yield due to increasing erosion rate with extensive expansion of plantation and bare land area around Bandung Municipal, which is mainly concentrated across the northern and southern parts. Summary of modeling results is given in Tables 7 and 8.

Table 7 Summary of overall modeling result.

Computed Parameters	1994 Range	1994 Mean	2001 Range	2001 Mean	Change of Mean (%)
E (tons/km^2/year)	3.2-7.3×10^6	23007	10.9-7.3×10^6	25131	11.1
SDR	2×10^{-4}-0.96	0.071	2×10^{-4}-0.96	0.071	0
Y (tons/km^2/year)	1.2-5.5×10^4	924	1.2-5.5×10^4	1022	7.3

Table 8 Summary of mean *E*, *SDR*, *Y* and total of *Y* per catchment sub-division.

Catchment Sub-division	Area (km^2)	1994 *E*	1994 *SDR*	1994 *Y*	1994 Y_{tot}	2001 *E*	2001 *SDR*	2001 *Y*	2001 Y_{tot}
Cisarea	350	10590	0.205	3020	410666	12272	0.204	3205	432626
Cisangkuy	295	7307	0.250	2019	387710	8398	0.253	2056	413320
Ciwidey	259	8973	0.264	2887	444604	9508	0.265	3095	467371
Cikapundung	299	5707	0.211	2370	405260	5840	0.211	2610	456821
Citarik	506	6707	0.199	2079	384655	7149	0.198	2303	449037

Notes: *E* in tons/km^2/year, *Y* in tons/km^2/year, Y_{tot} in tons/year

4 Conclusion

Set up of a spatial model applied in GIS environment for simulating regional sediment transport process of the UCC has been carried out and the results have been presented. Annual sediment yield is computed on the basis of product of erosion rate and *SDR*. USLE is used to estimate spatial distribution of erosion rate across the catchment. *SDR* is modelled using estimation of sediment resident time at the hillslope and channel network by calculating water flow velocity throughout sub-catchment surface and drainage network. Controlling factors due to geometry, physical characteristics and properties of catchment surface are considered. Accordingly, data from relevance authorities are used. It is expected that modeling would help in making decision for prioritising effort for erosion control.

The result generally shows natural extent of spatially distributed erosion rate and *SDR*, which is mainly controlled by distance to catchment outlet, slope and type of land use. Relation between *SDR* and catchment area confirms theoretical trend of decreasing *SDR* with increasing catchment area. The computed total sediment yield agrees quite well with respect to those measured in the field. Additionally, the effect of seven-year land use change in terms of deforestation is also observed. Increasing of the extent of exposed landscape resulted in increasing of erosion rate and sediment yield. Bearing in mind limited knowledge of some governing factors due to lack of observation, the overall result shows the potential of latest GIS features for spatially modeling regional sediment transport.

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