GIS APPLICATION FOR SEDIMENT CONTROL AT CATCHMENT AREA OF SEMPOR RESERVOIR, CENTRAL JAVA PROVINCE, INDONESIA

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ABSTRACT

Sempor reservoir is located in Kebumen Regency of Central Java Province, Indonesia. This reservoir is the strategic asset that play a crucial role in providing water for various needs. Currently, Land farming activities in the upper stream area tend to aggravate sediment problems. However, the way to solve this crucial problem hasn't found yet due to the increasing of sediment yield. The aim of this study is to determine the significant variable which controls sedimentation through appropriate land allocation.

Several scenarios are applied on determining the significant of sediment control. Period of time and the capacity of land use are also taken into account in this research. Landuse arrangement is designed by changing permanent vegetation cover into the other types of appropriate vegetations around 4% up to 30%. Formulas of Meyer-Peter and Müller as well as regression equations will be used to calculate the sedimentation. While, erosion will be simulated for ten years (2001 – 2011) using USLE equation then be supported by Arc GIS software. The results show that the increasing of permanent vegetation cover can reduce the sedimentation significantly.

Keyword*: sedimentation, land use, GIS*

INTRODUCTION

Sempor reservoir is the area which is located in Kebumen Regency, Central Java Province. This reservoir has been operating since 1987. It is designed for 50 years operation with dead storage 437,805 m^3 (BBWS.SO, 2009). Sempor reservoir has a function as estuary from two major rivers in recharge area which are Sampang and Kedungwringin (Figure 1).

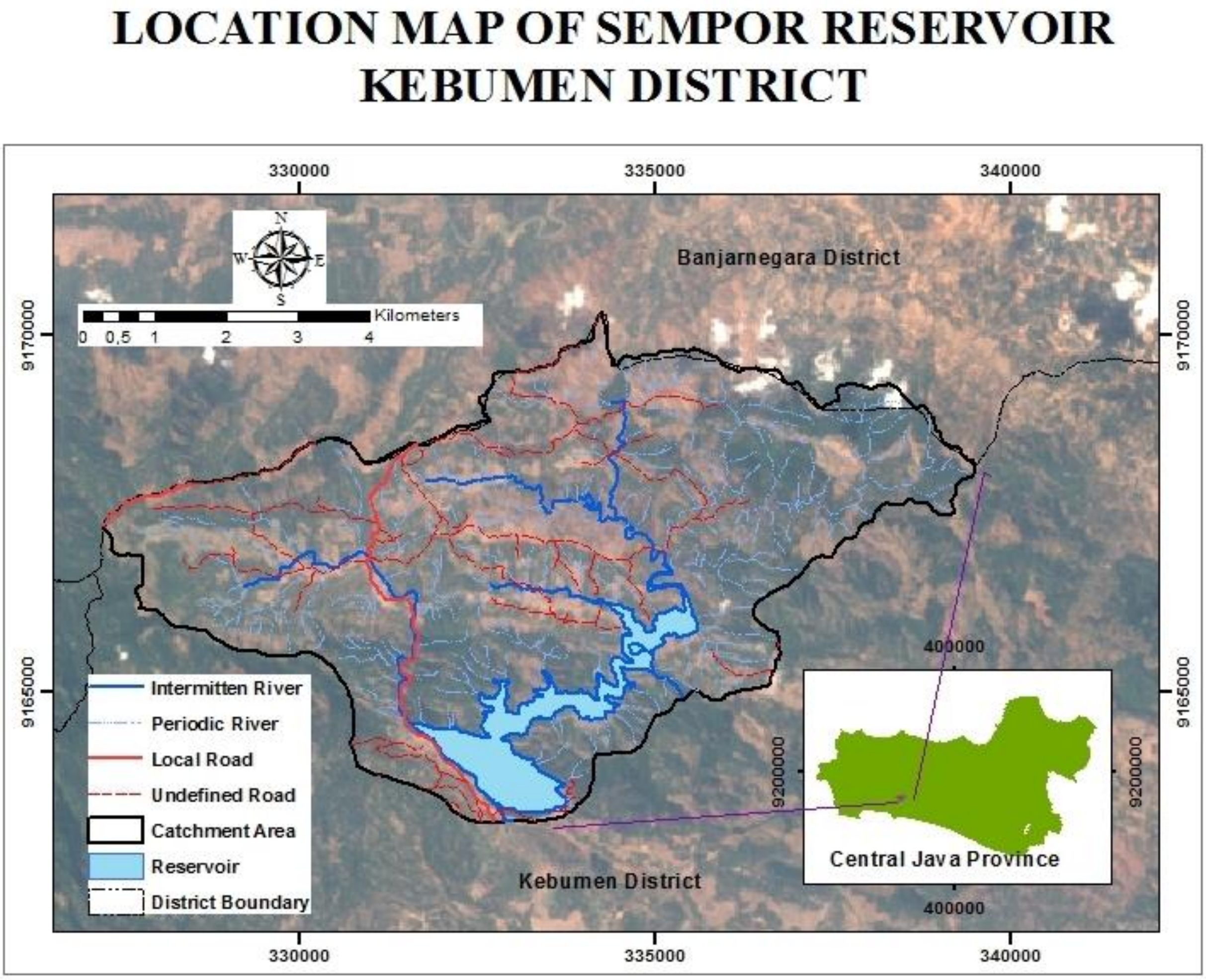


Figure 1. Cathment Area of Sempor Reservoir

Sempor reservoir is under semi-critical up to critical condition, recently. Semi-critical condition covers 1,796 Ha or 41.53% of the entire area. This condition is characterized by light erosion of land, less fertility of soil, 60-90 cm of solum depth, land cover area 50-75%, slope degree <15%.   However, the reservoir which is covered by critical condition is 1,797

Ha. The critical condition area is characterized by heavy erosion, soil depth <60 cm, less fertility of soil, land cover area 25-50%, slope degree 15-30% (Ananto et al., 2007).

There is 130,000 m^3/year of sediment getting into the reservoir through Sampang and Kedungwringin rivers. This amount, actually, has exceeded the annual standard limitation of sediment which is (121,000 m^3/year). The sediment is derived from high land erosion process due to inappropriate land use, especially agricultural activities (Figure 2).

Figure 2. Agricultural land condition in the upper part of Sempor reservoir

Land degradation of research area is occurred in two sites. Those two sites are in the upper part of reservoir (on-site) which is erosion process occurred and in the lower part of reservoir (off-site) which sedimentation takes place. Degradation of land in the research area was caused by diminishing of physical and chemical soil material such as losing of organic materials, increasing of soil density, decreasing of infiltration capacity, and decreasing of soil capability to withstand water (Arsyad, 2006).

Erosion process in a soil with natural condition such as soil in a forest takes a very slow rate. The slow rate of erosion process in such area causes the soil destructing and soil developing gets in a balance position. The erosion process is very controlled by climatic factors for instance rainfall intensity, topography, soil characteristic, land cover, and land use (Asdak, 2007).

To prevent from erosion and flood occurrences, some behaviors are needed to improve land use planning and applying some efforts to conserve water and soil (Fangmeier, 2006). Sempor reservoir which has an essential role for water system conservation, recently, has been changing physically either for land cultivation or land management. According to those facts, it is really important to conduct land management analysis for erosion controlling (Troeh, 2004).

METHODOLOGY

Erosion assessment was conducted through USLE method. Rainfall data from some rainfall station, soil saturated data, slope degree, and land use were applied as the input data for this analysis. Simulation was conducted through erosion assessment in existing condition where permanent land cover index (IPL) such as forest, bush, and grass about 4%. After that, those index are compared with erosion value occurred in scenario I condition up to scenario III condition. In scenario I, IPL was changed into 10% . However, in scenario II and III, IPL was changed into 20% and 30%.

Overlay processing in erosion assessment was conducted through USLE method running with Arc View software. Intersect function in Geoprocessing tools was applied (see Figure 3). ArcView software takes a part in mapping processes such as Recharge area map of Sempor reservoir, rainfall map, soil map, slope map, and land use map. Besides, this software also has a role for overlaying process for four basic map to obtain a land unit which has R value, K value, LS value, and CP value. Polygon thiessen assessment also was processed using ArcView software for combining with recharge area map and rainfall station.

There are four maps using in overlaying process which are polygon thiessen map, soil map, slope map, and land use map. The thiessen map gives the information about rainfall erosivity value (R). Soil map gives information about soil erodibility value (K). Slope map gives the information about slope value (LS). Then, land use map gives the information of land cover value (CP). A number of land units were produced as a result of overlaying process. Each of land unit gives different erosion value. In scenario I, II, and III, the land unit which were changed into permanent IPL is the land unit having high erosion rate (180-480 ton/ha/year) and the highest erosion rate (>480 ton/ha/year).

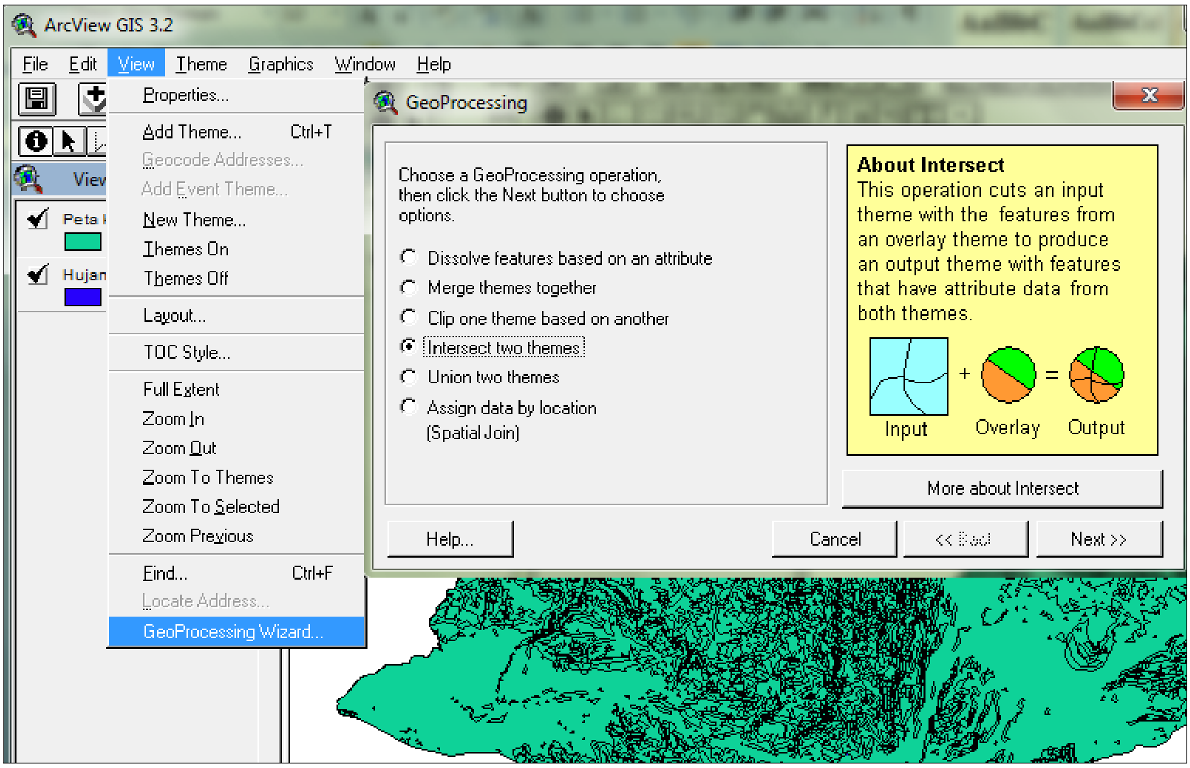
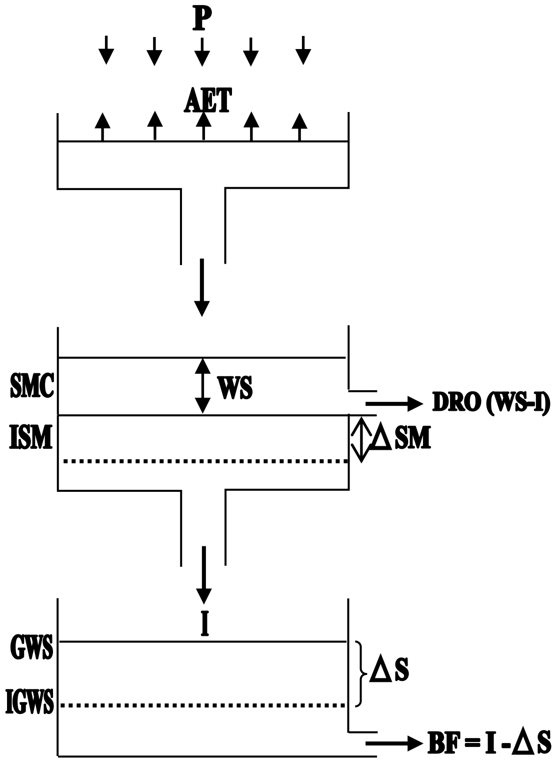


Figure 3. Intersect program in Geoprocessing ArcView 3.2

Geoprocessing extension is able to run overlay function. Two basic maps could be combined into one result map using overlaying process. If there are more than two maps which is going to combine, two or more steps of overlaying are needed.

Simulation of hydrologic processes

Mock hydrologic model of rainfall-discharge (Mock, 1973) is used to simulate water discharge as a part of measuring sedimentation at cathment area of Sempor Reservoir (see Figure 4).



AET = CF X ETO
ER = P – AET
WS = ER - ΔSM
ISM = SM_{I-1}
ISM_{FEB} = SM_{JAN}
IGWS = GWS_{I-1}
$IGWS_{FEB}$=GWS_{JAN}
I = C_W X WS = C_D X WS
GWS = 0,5 X (1+K) X I + K X IGWS
Q_{BAS} = I-ΔS = I – (GWS – IGWS)
Q_{TOT} = DRO + Q_{BSF}

where :
P = rainfall (mm)
CF = crop factor
AET = actual evapotranspiration (mm)
ER = excess rainfall (mm)
DRO = direct runoff (mm)
WS = water surplus (mm)
ĀSM = change of soil moisture (mm)
SMC = soil moisture capacity (mm)
ISM = initial soil moisture (mm)
ĀS = change of ground water volume
IGWS = initial ground water storage
GWS = ground water storage

Figure 4. Model Structure of Mock

Sedimentation from suspended load can be approached by using regression of discharge and suspended load. Bad load sedimentation is calculated using *Meyer-Peter and Muller's* method (Soemarto, 1999). Sedimentation was calculated for two major rivers such as Sampang dan Medono. Total sediment is amount of suspended load and bed load. Suspended load assessment was run using this regression equation: $Q_s = aQ_w^{b}$, (Geodeco, 1994) .

Sungai Sampang $Qs = 0.711Q_w^{1.077}$……………………..……………………………..(1)

Sungai Kedung Wringin $Qs= 0.322\ Q_w^{1.582}$……………………………..………………(2)

Qs is a suspended load however Qw is river debit. Transported process of bed load can be calculated using *Meyer-Peter and Muller's* formula with the equation follow (Soemarto, 1999) :

$$\gamma w \left(\frac{Ks}{Kr}\right)^{1,5} RS = 0,047\ (\gamma s - \gamma w)d + 0,25\ \rho^{1/3} Qb^{2/3} \quad \text{……………………………(3)}$$

Where γw is bulk density of water (ton/m3), γs is bulk density of sedimen (ton/m3), R is hidrolik diameter (m), S is river base slope, d is diameter median, ρ is volume density (ton sekon/m4) and Qb is river water tabel which is obtained from the kalibrassion (Yudi, 2005) :

Sampang River Qw = $27.955 \times H^{2.119}$……………………..………………...………..(4)

Medono River Qw = $0.322\ Q_w^{1.582}$………………………..……………..………..(5)

RESULT AND DISCUSSION

Land Use of the Upper Part of Sempor Reservoir

The function of upper part is as the recharge area of reservoir. Land use in research area is important to keep water sustainability for the reservoir. Land use of the upper part of Sempor Reservoir is dominantly food crop agriculture (Table 1), however the function of upper part should be conservation area with permanent vegetation. Infiltration process is not intensive and soil erosion is accelerated. Concequently, it reduces water storage.

Table 1. The Upper Part Land Use of Sempor Catchment

No	Land Use	Area (Ha)	%
1	Shrub	152.67	3.457114972
2	Building	0.04	0.000905775
3	Forest	0.5	0.011322182
4	Garden	3,081.30	69.77407719
5	Settlement	278.37	6.303511461
6	Grass	11.18	0.253163984
7	Irigation Rice Field	27.38	0.620002672
8	Rainfed Rice Field	300.25	6.798970134
9	Dry Field	308.82	6.993032329
10	Water Body	255.6	5.787899305
Total (Ha)		**4,416.11**	**100.00**

Source : Topographycal Map (2000)

Calculation of Soil Erosion and Sedimentation

Mock Model was calibrated to calculate water discharge data of the upper part of Sempor Reservoir. The value of correlation coeffisien is 0.98. sediment from the recharge area of Sempor Reservoir was 3.42 mm/year. Annual soil erosion rate in current condition is

12.5 mm/year. The value of sediment delivery ratio (SDR), the ratio between soil erosion and sedimentation, was 0.27. SDR value was useful to determine soil erosion rate on scenario I, scenario II, and scenario III. The results of the three scenarios of land use is in Table 2 and the actual condition of the three scenarios was shown in Figure 4.

Tabel 2. Comparison of Erosion Value with Land Use Planning

Land Use Simulation	Erosion (t/ha/year)	Erosion (mm/year)	Erosion Hazard	Sedimentation (mm/year)
Actual Condition	225.24	12.51	High	3.42
Scenario I	133.80	7.43	Moderate	2.03
Sceario II	115.95	6.44	Moderate	1.76
Scenario III	112.70	6.26	Moderate	1.71

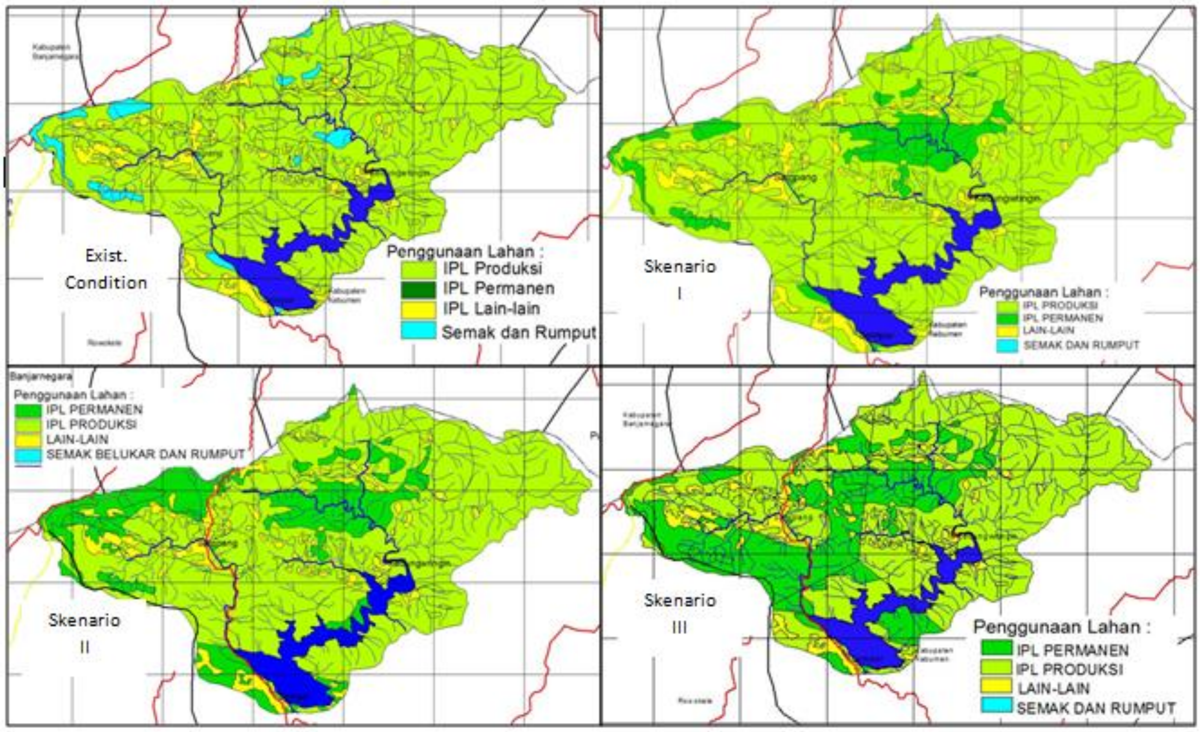


Figure 4. Actual Condition of Three Land use Scenarios

The decreasing of sedimentation from existing condition to scenario I condition is occured significantly. However, the decreasing of sedimentation is not significant from scenario I to scenario II and from scenario II to scenario III. The reason is the selected land unit of scenario I that has high to very high soil erosion rate is selected and changed into forest with permanent vegetation. In order to obtain the scenarios some basic maps were used (Figure 5).

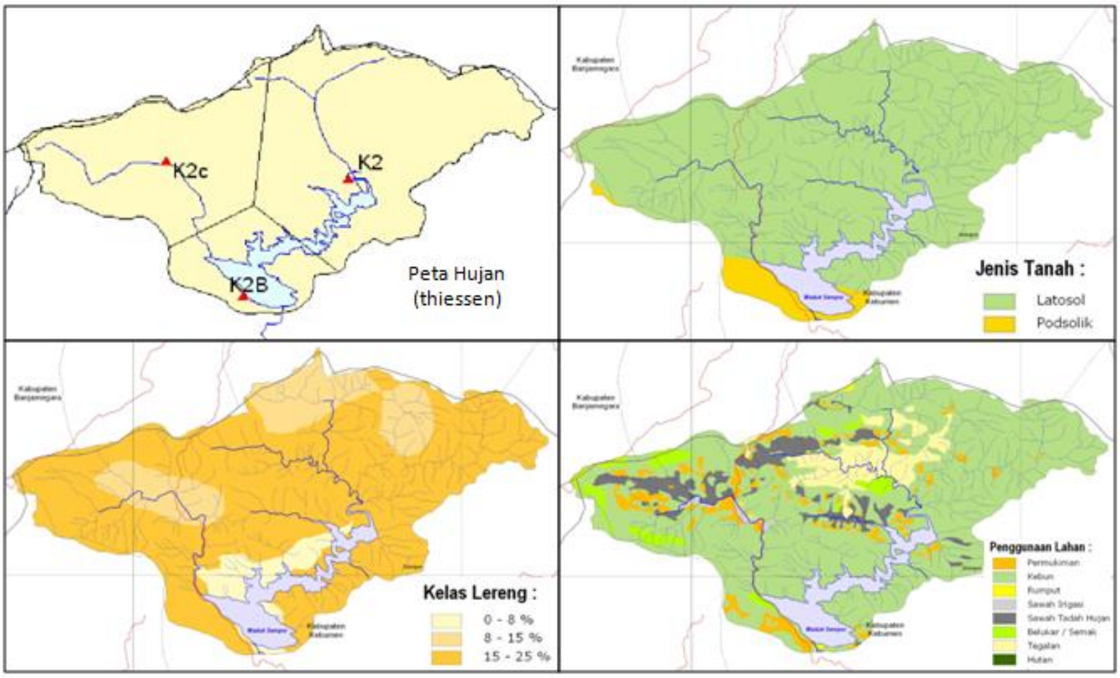


Figure 5. Maps used on overlaying process

Sedimentation is the concequency of soil erosion. They have the same factors, such as climate, topography, vegetation, soil, and human. The sedimentation mitigation can be applied by managed the managable factors through land conservation.

CONCLUSION AND RECOMMENDATION

Annual sedimentation in the recharge oarea of Sempor Reservoir in existing condition is 3.42 mm/year. Scenario I reduces sedimentation value into 2.03 mm/year, scenario II reduces sedimentation value into 1.76 mm/year, and scenario III reduces sedimentation value into 1.71 mm/year. Vegetative conservation and sediment control structure are useful to minimize sedimentation rate. Watershed monitoring is very important to evaluate watershed sustainability.

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