GEOGRAPHIC INFORMATION SYSTEM APPLICATION TO ANALYZE TOLERATED EROSION FLOW IN MAMASA CATCHMENT AREA

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ABSTRACT

Geographic information system currently used in various fields, such as land suitability mapping, erosion studies and transmission network planning. To study the estimated amount of erosion of soil loss can be easily obtained by calculating and overlaying maps which are components of Modified Universal Soil Loss Equation (MUSLE). GIS applications of the results obtained less than 35% of the watershed has Mamasa erosion rate is still tolerable, which is the region with the use of forest land and paddy fields, with a value of TSL 22.17 tons/ha/yr.

Keywords: GIS. Erosion, Watershed Mamasa

ABSTRAK

Sistem informasi geografis saat ini banyak digunakan diberbagai bidang, seperti pemetaan kesesuaian lahan, studi erosi dan perencanaan jaringan transmisi. Untuk studi erosi estimasi besarnya kehilangan tanah dapat dengan mudah diperoleh dengan mengkalkulasi dan overlay peta yang merupakan komponen *Modified Universal Soil Loss Equation* (MUSLE). Dari hasil aplikasi SIG diperoleh kurang dari 35 % wilayah DAS Mamasa mempunyai laju erosi yang masih dapat ditoleransi, yang terdapat pada wilayah dengan penggunaan lahan hutan dan persawahan, dengan nilai TSL 22,17 ton/ha/thn.

Kata Kunci : SIG. Erosi , DAS Mamasa

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INTRODUCTION

The need for GIS technology is based on reasons such as the volume of data handling and environmental resources which are generally very large, so the conventional method is difficult to handle. Data collection is usually complex and complicated, demanding the use of data management system effective. besides that, the current GIS development is supported by things like urgency to do the repair process (refinement) of cartography, the increasing ability of computerized systems in line with the increasing ability of computerized systems in line with the ever-expanding hardware and software, and the revolution quantitative analysis of spatial information is generally used in planning and environmental management.

Assessment of watershed areas or sub-watersheds can cover vast areas with very varied conditions, so that the data required considerable time and relatively long analysis. Therefore, it is required a method or tool that can access and analyze data quickly with a level high enough accuracy. for that, GIS is able to process and analyze data/information on climate, regional characteristics and land, incorporating in the form of digital maps / images, so analysis of the degradation of watershed areas can be done. Mamasa catching regional characteristics with soil and geological conditions are very unstable, due to destruction of forest vegetation illegal logging and moving farming systems and use of land without conservation measures by some people is a major cause of erosion in these areas. With the increasing complexity of the problems in the watershed area calls for the complete data and accurate and representative of the characteristics of the watershed in order to control and management

METHODOLOGY

Data Collecting and Processing

Stage One: Conduct observations watershed biophysical conditions and collection Mamasa secondary data, such as: administrative maps, map soil types, slope class maps, land use maps and map precipitation polygons with a scale of 1: 300,000. The results of the combination of these maps form a map which is used as a working map.

Stage Two: Collecting data hydrological/climatologically Mamasa catchment area during the last 10 years are tabulated and analyzed to obtain the average state daily, monthly and yearly.

Stage Three: Coordination and clarification area, location and situation and position of the map of the watershed Mamasa related agencies for the purposes of identification and location of the plot area on the map and the way the earth RLKT pattern Mamasa catchments area.

Stage Four: Scanning maps for watershed digitasi Mamasa and interpretation and analysis of computational maps of biophysical conditions Mamasa Watershed (software applications MapInfo / Arcview) to define land units. Thematic maps that use a method parameter MUSLE (Modified Universal Soil Loss Equation), namely rain erosivitas factor (R), soil erodibilitas factor (K), length and steepness factor slope (LS), crop factor (C) and management factors plant and soil conservation (P). Calculating the total area of the upper region, middle and downstream of computing and calculating the maximum limit soil erosion can be tolerated (TSL).

MUSLE Model

Soil Erosion prediction calculated by the equation:

$$A = R \times K \times L \times S \times C \times P \qquad (1)$$

Rain Erosion factor (R) is calculated with the equation proposed by Bols (1976) in Suripin (2004):

$$R = \sum_{i=1}^{n} EI_{30,m} \qquad (2)$$

$$EI_{30,m} = 6{,}119 R_m^{1{,}211} N^{-0{,}474} R_{MAX}^{0{,}526} \quad (3)$$

Where: EI30, m = monthly Erosion (KJ/ha), Rm = monthly rainfall (cm), N = number of rainy days per month (days), RMAX = maximum daily rainfall (cm). Erosion factor (K) obtained from the analysis of soil samples. As a comparative value of K can also be obtained with the help monographs' presented by Wischmeier (1978) is by knowing the soil texture, soil structure, organic matter and soil permeability. Factors Slope length and steepness (LS), calculated based on the formula proposed by Williams and Berndt (1972) in Suripin. (2002):

$$LS = \sqrt{\frac{L}{22{,}13}^{2}} \left(0{,}065 + 0{,}0453 s + 0{,}0065 s^{2}\right) \qquad (4)$$

Where: L Length of slope (m), S slope steepness (m/m), L is determined from $L = \dfrac{0{,}5A}{LCH}$ where the total length of LCH is the channel/river (m) and A is the catchment area (m^2). Crop factor (C) is determined based on the values expressed by the River Research Agency (BPS), Indonesia (1989), Arnold (1977), Arsyad (2006). Map of land use or land cover maps used are Mmasa watershed land cover scale 1: 100,000. Value of C varies between 0.001 to 1.0 where vacant land or fallow land is 1 and lowest in forest-covered organic mulch materials or cover enough ground, namely 0.001. Management factors Crop and Soil Conservation (P), is the ratio of the amount of erosion of land with specific conservation measures to the amount of erosion of standards of land without conservation measures. Input values for the factors of soil conservation measures are determined based on research that has been done in Indonesia. For plants without soil conservation measures, the value of factor P = 1.

Erosion that can be tolerated (TSL)

Hammer (1981), introduced the concept of loss that can be left (TSL) by considering the age of land use, time needed to run out tererosinya a soil depth, with the equation:

$$TSL = \frac{KE\,x\,FK}{UGT} \text{......................(5)}$$

Where, TSL = erosion rate that can be tolerated (tons/ha/year), KE = effective soil depth (mm), FK = factor of depth of soil sub-orders and UGT = age in order to land (for 400 years of conservation interest).

RESULTS AND DISCUSSION

Mamasa Basin area

Mamasa Watershed in Mamasa District, Pinrang and Polewali, which includes 4 districts and 48 villages. Mamasa River has a length of 113.75 km main river, while the length of 172.50 km tributary which flows from north to south with catchment area 1061.7803 km^2. Mamasa Basin area is at an elevation of about 60 to 2873 m above sea level. Most of this area is a hilly area with gradient 15% to> 45%.

In the lower watershed areas there Mamasa Bakaru hydropower reservoir with an area of 199.85 ha is located in the village of Ulu Saddang, Pinrang. These reservoirs, except as a source of raw water and water irgasi for local communities, as well as Water Power (hydropower).

Erosion Estimation

Erosivitas (R)

Climate elements enormous influence on the process of erosion is rainfall. Based on the kinetic energy of the annual rainfall, watershed area Mamasa divided into five regions of rain (isohyet), which each represented by station Lemo, Sumarorong, Mamasa, Mambi and Tuppu Station. Rainfall data as inputs include the average annual rainfall, which is used to predict the amount erosivitas. Average annual rainfall at the five stations on the ranges between 543 mm - 2127 mm with a 41-day rainy day - 143 days. The value for the region erosion Mamasa Watershed ranges from 100 to 2800.

Table 1: Region of Rainfall in The Watershed Mamasa

No	Erosion Value	Area (ha)	Area (%)
1	100 - 500	5863,67	5,52
2	501 – 1010	20513,73	19,32
3	1011 – 1600	22616,89	21,30
4	1601 – 2200	46251,34	43,52
5	2201 – 2800	10935,43	10,29
	Total	106178,03	100

The nature of rain is important in the erosion of rain intensity, rainfall amount and distribution of rain (Utomo, 1989). The intensity of rain refers to the number of rain per unit time. The intensity of rain is said when rainfall occurs a large amount in a short time.

While the amount of rain refers to the number of rain water during the rain in a certain time. The amount of rainfall may not necessarily lead to erosion if the small intensity, as well as high rainfall, but in small amounts, probably will not cause erosion because not enough water to wash away dirt particles. Erosion can occur if the rain that has occurred and the amount of high intensity. According to Hudson in the Seta (1991), soil erosion will occur if the intensity of rain is greater than or equal to 25 mm/hour.

Erodibilitas (K)

Each type of soil has a difference in resistance to erosion. Ease of a soil erosion erodibilitas known as the land. Erodibilitas value of land mainly influenced by physical factors such as soil texture, structure, permeability and organic matter content in soil, which determines the sensitivity to erosion (Nyakatawa, et al. 2001). Soil types found in the watershed area and the value of Mamasa erodibilitas (K), are presented in Table 2.

Table 2: Soil Type and Land Erodibilitas Value (K) in The Watershed Mamasa

No.	Soil Variety	Erodibilitas?	area(ha)	area (%)
1.	Podsolik Coklat	0,10	21599,65	20,34
2.	Compleks Yellow Brown	0,15	47072,01	44,33
3.	Brown Forest Soil	0,21	37506,37	35,32
		Total	106178,03	100

Textured soil with high porosity resulted in water easily seep into the ground, a small surface flow thus reduced erosion. Similarly, land that has a solid structure, not easily destroyed by the rain blows, this land will be resistant to erosion. On the other hand soil structure is not stable, very easy to be destroyed by the blows rain into fine grains that cover the soil pores. As a result infiltration and inhibited the flow of surface increases, which means an increase in erosion.

Permeability of soil is closely related to infiltration. Infiltration is an event of water entry into the soil through the soil surface. If the infiltration of ground, then the young water to seep into the soil surface so that the flow becomes smaller, the result of erosion that occurs will be small too. While soil organic matter content determined the sensitivity of soil to erosion. Soil contains enough organic material generally causes soil structure to be established so that the resistance to erosion. Soil containing <2% are generally sensitive to erosion (Morgan, 1979)

Topography (LS)

Mamasa Basin area has a topographic conditions are extremely varied, ranging from flat, sloping, a little steep to very steep, with elevation from sea level (above sea level) between 60 to 2873 m. Topographical factors that most influence on the long slope erosion and slope. According to Angima, et al, (2003), slope of land will affect the land productivity. Mamasa Basin area is dominated by undulating to hilly topography with a width of approximately 42,338.31 hectares or 39.87% of the total watershed area and the topography is quite steep 33,279.70 hectares or 31.34%. Only 1.70% of the watershed which is a plain Mamasa, consequently it is possible the rate of surface flow (runoff). Because the process flow of the faster surface by the growing percentage of slope (Suripin, 2004). The value of topographic factor (LS) based on slope length and slope in the watershed areas ranging from Mamasa 0.10 to 11.78.

Table 3: Slope and slope factor values in The Watershed Mamasa

No.	Slope (%)	LS value	area (ha)	area (%)
1.	0 - 8	0,10	1.825,01	1,70
2.	8 – 15	0,88	14058,30	13,24
3.	15 – 25	4,09	42338,31	39,87
4.	25 – 45	8,37	33279,70	31,34
5.	> 45	11,78	14678,71	13,82
		Total	106178,03	100

Crop and Crop Management (CP)

Land use is human activities that give the greatest influence on erosion. Plants or vegetation cover can prevent rain water from falling directly on the soil surface, so that rain water power to destroy the land is reduced, depending on the density and height of plants, plant closer, more effective in reducing erosion. In Arsyad (2006) said that, a plant or vegetation cover good ground like thick grass or dense jungle will eliminate the influence of rain and topography of the erosion. Because the human need for food, clothing and housing is increasing, all the land cannot be left closed forests and grasslands. Other plants are cultivated by humans play a significant role in the prevention of erosion. In general, the application of conservation in watershed areas Mamasa inadequate, more than 85% of watershed land use is still a forest and scrub / grassland. Only about 13.94% of the paddy fields, mixed gardens and fields by implementing simple conservation methods, such as the use of traditional patio and planting according to the contour on sloping land areas above 20%.

Table 4: Factor Value Crop and Crop Management in The Watersdeh Mamasa

No.	Land Use	CP value	area (ha)	area (%)
1	Forest	0.005	54126,20	50,97
2.	Paddies	0.050	2261,72	2,13
3.	Bush	0.300	37254,55	35,09
4.	Mixed Plantation	0.200	2684,70	2,53
5.	Moor	0.400	9850.86	9,28
		Total	106178,03	100

Land Unit

Land units is a unit of land that the area relatively uniform erosion over a number of factors. Wischmeier and Smith (1978), states that an important consideration in the application of erosion prediction models in watershed areas is to classify watersheds into sections or areas of land units are relatively uniform over a number of factors of erosion. Unit of land acquired by the map overlay of climate, soil maps, slope maps and land use maps. In the watershed area of Mamasa overlay results yielded 584 units of land in the watershed area of 106,178.03 ha. In GIS analysis, land units were given identity numbers, area information and location of each unit of land in large quantities, integration of watershed area as a whole, which is very difficult to manually and takes a long time.

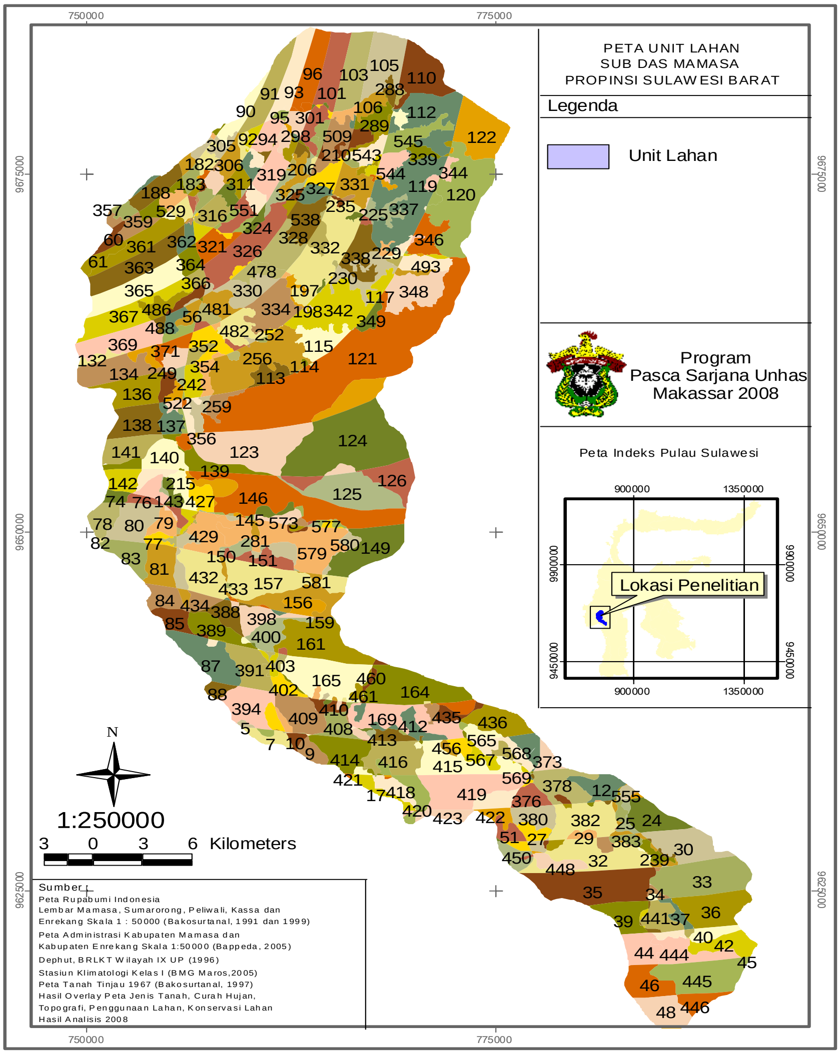

Figure 1: Land Units Map in The Watershed Mamasa.

The rate of Soil Erosion

Erosion rate is calculated by using GIS-based MUSLE model, which is based on various factors of erosion. The rate of erosion in the watershed area Mamasa reach 23,783,321.05 tons / year or an average of 718.61 tons / ha / year. The largest rate of soil erosion in watershed areas Mamasa, occurred in the use of shrubs is 256.29 tonnes/ha/yr, and then mixed garden 243.25 tons/ha/yr and moor 201.65 tons/ha/yr, this is caused by land use for these activities, generally performed on cycle region and the lack of public awareness to action in the business of land conservation land use, consequently increasing the surface flow that results in increased erosion rate.

Table 5: The rate of Soil Erosion Land Use For Each Mamasa Watershed

No.	Land Use	area (ha)	Erosion(ton/ha/year)
1.	Forest	54126,20	5,51
2.	Paddies	2261,72	11,91
3.	Bush	37254,55	256,29
4.	Mixed Plantation	2684,70	243,25
5.	Moor	9850,86	201,65
	Total	106178,03	718,61

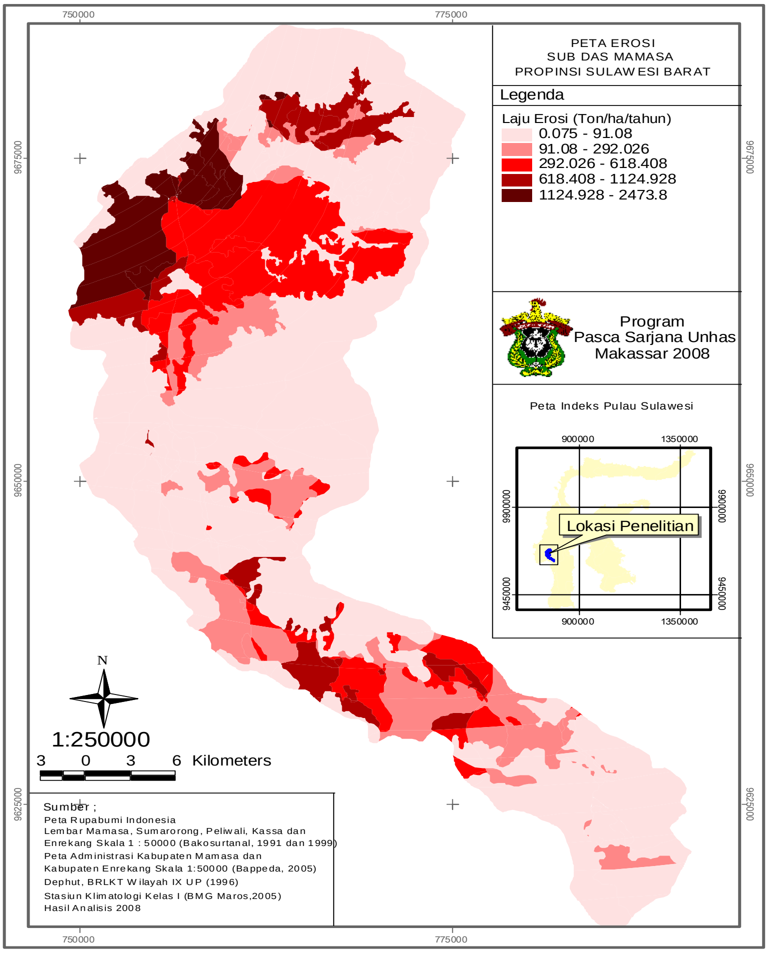

Figure 2: The Rate of Soil Erosion Map in The Watershed Mamasa.

<u>*Tolerable Soil Loss (TSL)*</u>

Determination of the highest erosion rate limit that can be tolerated or ignored, because it needs to be done by pressing may not reached zero erosion rate of soil on agricultural land, especially on the ground slope area (Arsyad, 2006). Value erosion rate that can be tolerated (Tolerable Soil Loss) traced on the basis of effective depth of sub-orders, the value and age factors into a land (Hamer, 1982). TSL value for watershed areas with soil types Mamasa Compleks Brown, Brown Forest Soil and Brown Podsolik obtained respectively 20, 25 and 20 tons/ha/year, assuming an effective soil depth of ≥ 100 cm used by the consideration that, in the area of land Mamasa watershed land belonging to the advanced level of development.

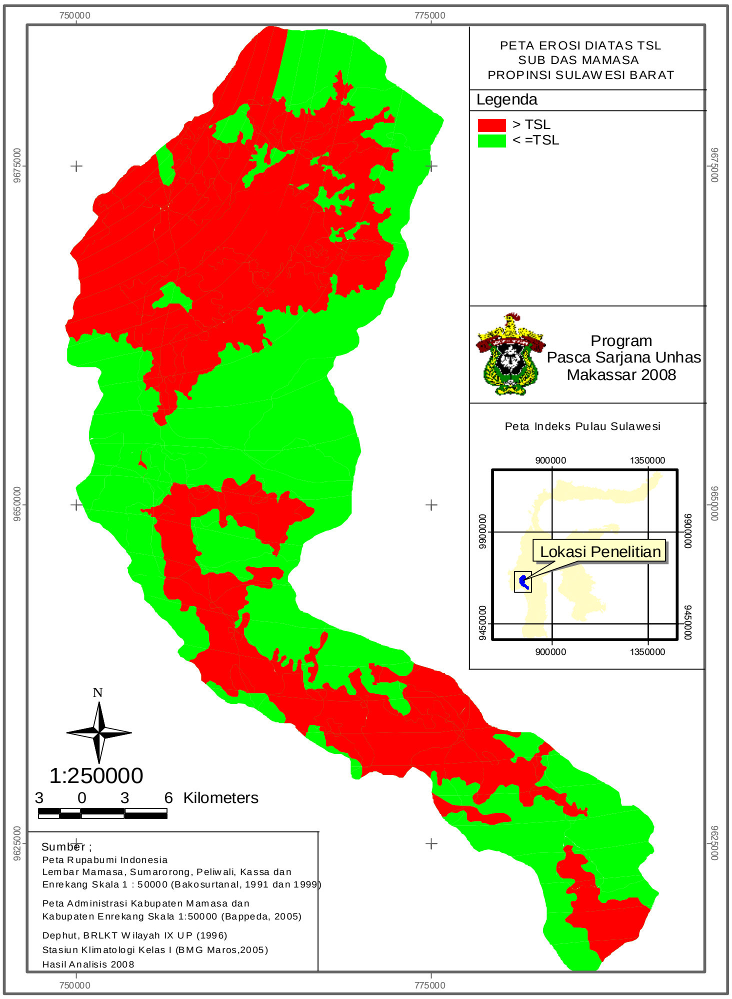

Figure 3. Erosion Tolerable Map in The Watershed Mamasa

In these images, can be seen that about 65.92% of the watershed has Mamasa erosion rate greater than its TSL, and only less than 35%, the rate of erosion in the region which can still be tolerated. Erosion rate which is tolerable in the use of forest land and paddy fields. However, if the forests and rice paddies are not kept and managed well, then it might be damaged in the future and increase the rate of erosion in this area. While the rate of erosion on land-use shrubs, gardens and fields mixture much greater than the value of TSL. If this is allowed to proceed, then the land will be degraded, declining land productivity and agricultural production as a result, could decrease as well. Besides resulting in a decline in agricultural production is closely related to farmers' income and welfare, high erosion can also cause bad effects on the environment, floods and droughts. Thus the immediate treatment necessary to control, good handling mechanical soil conservation in the form of terraces or vegetative cover by planting vegetation. Changes in land use and management can reduce erosion rate to reach a value less than or equal to the TSL value of Mamasa catchment area.

CONCLUSION

Erosion rate for each land use in watershed areas Mamasa respectively: the forest is 5.51 tons/ha/yr, i.e. bush 256.29 tons / ha / yr, i.e. mixed garden 243.25 tons / ha / yr, rice field i.e. 11.91 tons/ha/yr and the field of 201.65 tons/ha/yr, so the total erosion rate is 718.61 tons/ha/yr. Erosion rate that can be tolerated (TSL) in the watershed area Mamasa 22.17 tons / ha / yr. More than 65% of the watershed has Mamasa erosion rate greater than its TSL, and only less than 35%, the rate of erosion in the region which can still be tolerated.

REFERENCES

Arsyad, Sitanala., 2006. *Soil and Water Conservation.* Bogor Agriculture Institute. IPB Press.

Bartsch, K.P., Miegroet, H.V., Boettinger, J., and Dobrowoiski, J.P., 2002. *Using Empirical Erosion Models and GIS to Determine Erosion Risk at Camp Williams, Utah*. Journal of Soil and Water Conservation. Vol 57. No. 1.

Bols, P. L. 1978. *The iso-irodent Map of Java and Madura*. Report Belgian Technical Assistance Project ATA 105-Soil Research Institute, Bogor. Indonesia.

Hammer, W.I. 1981. *Soil Conservation.* Consultant Report II*,* AGOF/ INS /78/ 006. Tech. Note No. 10. Centre for Soil Research, Bogor, Indonesia.

Morgan, R.P.C., 1985. *Soil Erosion and Conservation.* ELBS. Longman Scientitic and Technical. England.

Nyakatawa, E.Z., Reddy, K.C. and Lemunyon, J.L., 2001. *Predicting Soil Erosion in Conservation Tillage Cotton Production System Using The Revisid Universal Soil Loss Equation (RUSLE)*. ELSEVIER. Soil & Tillage Research 57 (2001) 213 – 224.

Suripin., 2004. *Soil and Water Conservation*. ANDI Yogyakarta.

Utomo, W.H., 1989. *Soil Conservation at Indonesia a partnership and analysis.* Rajawali Press Jakarta.

Wischmeier, W. H. and D. D. Smith., 1978. *Predicting Rainfall Erosion Losse – A Guide to Conservation Planning.* USDA – SED Agricultural Handb. 14.4.408p.