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Prediction of Erosion Rate at Several Land Units in Upper Watershed of Batang Mangau, West Sumatera

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***Abstract*— Assessment of erosion in a watershed is very important for the purpose of determining whether a watershed has been degraded and damaged or not, so it is useful for the planning of the future for the watershed areas so as to achieve sustainable land use and environmentally friendly.Study of erosion prediction and mapping erosion hazard rate (TBE), and determine the rate of erosion that can be tolerated in a variety of land units, and determining alternative land use followed by the appropriate conservation measures in order to suppress erosion as small as possible or equal to Etol (tolerable erosion) has conducted research on upstream Mangau Padang Pariaman and Agam districts. The study lasted in September 2011 until January 2012. The experiment was conducted using the survey method. Secondary data obtained from statistical data, maps and the results of previous researches. The results showed that the greatest erosion occurs in people's gardens land units with steep slopes (KrF), with a percentage of 62% slope and slope length of 45 m. While the smallest erosion occurs in wetland units with a gentle slope (SWB), the percentage of 7% slope and slope length of 28 m. Land units experiencing mild erosion rate is 37.80%, of the total study area. Then the land units suffered heavy erosion rate is as much as 20.81%, and further land experiencing very severe erosion hazard level is sebayak 37.86% of the total study area. Actual erosion rate greater than can be tolerated erosion found 4 unit of land is the garden of the people with a rather steep slope (KrD), mixed garden with a rather steep slope (KcD), and their fields with steep slopes (KrF). Furthermore, there are 8 land unit value erosion rate is less than the erosion rates that can be tolerated so that the use of the land does not need changing. Alternative use of land for every land units that have greater erosion speed of the tolerable erosion is the land units of protected forest with steep slopes (HlF), the secondary forest with steep slopes (HsF). Whereas, the land unit of rice paddy soil with relatively steep slopes (SwD), rice paddy soil with gentle slopes (SwB), scrub with relatively steep slopes (SmD), scrub with steep slopes (SmF) and farm people with mild slopes (KrB) fixed defended. Furthermore, the alternative use of the land for the unit of farm people with steep slopes (KrF) and farm people with relatively steep slopes (KrD) and a mixture of garden soil units with relatively steep slopes (KcD) is recommended for improved by adding high density mixed garden and make bench terrrace with good construction and land cover tightly coupled.**

***Keywords*— Prediction erosion; land unit; upper watershed; alternative landuse**

I. INTRODUCTION

A systems approach to the watershed (DAS) is very complex, because the watershed is an ecosystem that has its own characteristics which is the result of mutual interaction with living beings watershed supporting the physical and chemical environment in the watershed. Dynamic equilibrium of the system is always changing according to the time change. In its natural state, the balance changes will be slow and do not pose a threat preservation of the watershed (Mas `ud, 1987). The rapid increase of population in the catchment area will result in very heavy pressure on land due to human efforts to meet their needs and seek ways to work the land in the watershed slopes are steep with an emphasis on seasonal patterns of food crops farming. This will result in illegal deforestation, cultivation on slopes exceeding the carrying capacity of the land without any additional input for the improvement of soil fertility as well as not using the resource conservation measures, that will cause environmental damage and the deterioration of the quantity and quality of land resources in the watershed, and can interfere watershed ecosystem balance, which in turn will lead to deterioration of livelihoods of people who live in the catchment area (Haryanto, Santoso and Syafruddin, 1990).

When the land in a watershed is too often exploited, so the vegetation ground cover disturbed, then the amount of water in the basin that can be retained while much reduced, because during heavy rain, the proportion of rainfall that infiltrated and seriously percolation into the soil is reduced, so that fluctuations in the flow rivers and larger sediment load. Human action to exploit natural resources in the watershed in order to better meet their needs for food,

clothing and housing will cause disruption to the ecosystem as a whole watershed. If the DAS is an increase in the number of people very rapidly will result in severe pressure on land resources. In addition, residents often organize the land is not in accordance with his ability and without soil and water conservation measures. It has led to land degradation and critical watersheds.

Mangau upstream watershed is an area that many landslides occurred due to insecurity rocked by earthquake on September 30, 2009 and so a lot of residential land and agricultural land affected. State's diverse topography ranging from plains to mountainous areas with a slope ranging from gentle to very steep. Land use is generally a coconut grove, cinnamon, and rubber and moor, and settlements. Based on the research results of Saidi, Berd, and Fiantis (2010) lands in the upper watershed Mangau is very prone to landslides and of course will be very sensitive to erosion. This occurs because the soil parent material consists of pumice tuff material is very fragile and easy to be swept away by the water. Therefore, research on soil sensitivity to erosion for the watershed needs to be done.

II. Research Methodology

The study was conducted in sub-watershed upstream Mangau covering two districts of Agam regency (district Malalak) and Pariaman District (District Partamuan, Sarik River VII Koto, and South Pariaman district (Map Location 1) The study was conducted using a survey method. Field observations made on pit soil profile and soil sampling based on land units. Slope map-making based on the interpretation and analysis of existing contour lines on a topographic map. Slope grading is done using the formula Ellyas (1988), namely;

$$L = \frac{CI}{D} \times 10000/S \quad (1),$$

Where:
L = length of slope index,
CI = contour interval (m)
D = distance contours on the map (cm)
S = scale map,

TABLE I
GRADING SLOPES IN THE WATERSHED UPSTREAM OF MANGAU

No	Slope Gradient (%)	Symbol	Slope Class
1	0-3	A	Flate
2	3-8	B	Undulating
3	8-15	C	Rolling
4	15-25	D	Hilly
5	25-45	E	Slightly steep
6	45-65	F	Steep - very steep

Land unit map obtained by doing an overlay of soil maps, land use maps, and map slope (observational Map 1). Land unit map is illustrate piece of land that have similar characteristics in topography, land use. Determination of soil sampling locations possible based on purposive random sampling method that is at locations considered to represent the area of the map unit. Compilation map unit area can be described in Table 2.

TABLE III
LAND UNIT MAP OF MANGAU UPPER WATERSHED

No	Land Units	Land Uses	Slope gradients (%)	Areas (Ha)	(%)
1	Hl F	Protected forest	45-65	1039	11,10
2	Hs F	Secondary forest	45-65	863	9,20
3	Kr B	Peaple Garden	8-15	730	7,80
4	Kr D	Peaple Garden	15-25	2912	31,20
5	Kr F	Peaple Garden	45-65	2023	21,70
6	Kc D	Mixed Garden	15-25	874	9,40
7	Sw B	Sawahs	8-15	347	3,70
8	Sw D	Sawahs	15-25	438	4,70
9	Sm D	Bush	15-25	73	0,80
10	Sm F	Bush	45-65	35	0,40
				9334	100

A. Soil Analysis

Soil samples taken from the soil profile pit. Besides, it is also a composite sample taken for texture analysis with pipette and sieve method, and the method Wallkley Organic C and Black. Intact samples taken using the copper ring for permeability analysis. by the method of De Boodt based on Darcy's law, soil structure observed in the field using field observation LPT guidelines (1980

B. Determination of the Rate of Erosion or Erosion Hazards

The magnitude of the predicted erosion rates for each land unit in the sub-watershed upstream Mangau done using methods Wischmeier and Smith (1978) which is famous for the Universal Soil Loss Equation (USLE), namely;

$$A = RKLSCP \quad (2)$$

Where:
A = average soil loss (ton \ ha \ year).,
R = rainfall erosivity index,
K = soil erodibility index,
L = length of slope index,
S = slope index,
C = index crop management,
P = Index of land management,

1) *Rain Erosivity Index Determination:* Rainfall erosivity indices calculated from rainfall data (the amount of rainfall, number of rainy days, and the maximum amount of rainfall) in a month by using the formula Bols (1978) is,

$$\text{Monthly } EI_{30} = 6.119\,(RAIN)^{1,21}\,(DAYS)^{-0,47}\,(R\,max)^{0.53}$$

Where:
R = daily or monthly rainfall (cm),
N = Number of days of rain,
R max = maximum rainfall during 24 hours in a month,

2) *Erodibility Index :* Soil erodibility index can be determined by using the nomographs of Wischmeier and

Smith (1978) or calculated by the equation Weischmeler, Yonson and the Cross (1971), namely:

$$100K = 2{,}713\ M^{1.14}\ (10-4)\ (12-a) + 3.25\ (b-2) + 2.5\ (C-3)$$

Where :
K = Erodibility factor
M = percentage of fine sand and dust multiplied by (100-percentage of clay)
A = The percentage of organic matter (% C Organic x 1,724)
b = Code soil structure (Table)
C = code permeability of the soil (Table)

3) *Crop Management Factors :* Value of crop management factor (C) may be used by matching with state land use types that have been done in this research area (Appendix Table 1, 2, and 3). ,

4) *Soil conservation management factor (P):* Soil conservation management factors and cover crops (CP) allegedly based on field observations into account data from previous research (Appendix Table 4. 5.)

C. Tolerated erosion

Tolerable erosion can be calculated by using the formula;

$$T = [(DE-DM) / UT] + LPT$$

T = The rate of Tolerated erosion (ton / ha / year)
DE = Equivalent soil depth (cm) that comes from the results of multiple layers of depth up blockers.
DM = minimum soil depth required by the crop
UT = age in specified land at the speed where soil erosion is greater than the speed of soil formation.
LPT = Rate of soil formation (mm pertahum).

D. Alternative land use

Alternative land use can be gotten by the formula

$$CP \leq T/RKLS$$

where

T = Tolerated erosion
RKLS = Potential Erosion (ton/ha/years) With CP = 1
C = Crop management
P = land management

III. Results and Discussion

A. General Situation Research Areas.

1) *Regional Layout and Location Research*

Mangau watershed located administratively in Patamuan District Padang Pariaman Regency and Malalak district Agam regency. In Geography, Mangau watershed is located at 0 ° 20 '34 "S to 0 ° 32' 24" South and 100 ° 13 '21 "E to 100 ° 19' 53" E, with altitudes ranging from 25-2500 m from sea level.

2) *Climate.*

Climatic factors have great influence on erosion in the humid tropics is rainfall. Based climate classification system according to Schmidt-Fergusson, the climate in the study area belong to the climate type A (Very Wet). Rainfall data is based on the data obtained from the Climatological Station Sicincin Pariaman years 1999 - 2009 (Appendix 7).

3) *Topography*

Based on 1:50,000-scale topographic map interpretation and field checks on the slopes of the obtained 3 classes are presented in Table 3

TABLE IIIII
SLOPE CLASS OF MANGAU UPPER SUBWATERSHED

No	Topography	Slope Class	Slope (%)	Areas (Ha)	(%)
1	Undulating	B	3-8	1105,0	11,83
2	Somewhat steep	D	16-30	3026,0	32,40
3	Steep	F	45-60	5209,0	55,70
	Total			9340,0	100,0

Data from Table 3. shiwed that such as the topography of the undulating land with an area of 1105 ha (11.84%), somewhat steep with an area 3026 ha (32.42%), land topography steep with an area 5209 ha (55,77 %).

4) *Land Use (C) and Soil Conservation (P).*

Based on the land use map and checked in the field obtained some kind of land use. Value of crop management factors and land cover (C) is determined based on land use in the study area and to accommodate the members of the previous research on attachment as 10. The higher the CP then the possibility of greater erosion occurred, according to the opinion Arsyad (2000) that vegetation (crop management) affect soil erosion due to vegetation cover against damage by rain details. The influence of vegetation depends on the type of crops, rooting, plant height, heading and growth rate. Similarly, soil conservation techniques are performed.

B. Prediction of Erosion and Erosion potential

1) *Rain erosivity index (R)*

Rainfall erosivity index is calculated by using the formula Bols (1978). The result can be seen in Table 4.

TABLE IVV
AVERAGE MONTHLY RAINFALL, NUMBER OF RAINY DAYS AND A MAXIMUM RAINFALL OF 1999-2008 YEAR (MM / YR) AND RAINFALL EROSIVITY.

Monthly	Rainfall (cm)	Number of Rainfall	The Highest Rainfall	Erosivity
January	34,02	9,2	6,72	422,28
February	17,7	7,1	4,69	178,80
March	22,87	9,3	3,99	197,16
April	28,33	11,6	5,5	272,89
May	19,5	7,7	4,43	187,74
June	21,01	8,2	4,91	210,67
July	24,31	7,8	4,41	243,07
August	23,28	8,3	5,08	241,48
September	32,16	11,3	6,16	342,03
October	33,82	11,5	5,0	322,78
November	41,88	12	5,75	441,28
December	39,14	12,8	6,72	428,42
Total				3494,60

Table 4 showed that the rainfall erosivity index for the entire study area is 3494.60. Ability of rainfall intensity on soil erosion in the upper watershed of Mangau is relatively large.

2) *Soil Erodibility (K)*

Soil erodibility index for each land unit can be calculated using the formula Wischmeier, Jonson and Cross, 1971) is determined by the physical and chemical properties of the soil itself as soil texture, structure, permeability and soil organic matter content . The results are shown in Table 5.

TABLE V
VALUE ERODIBILITY (K)

No	Land Unit	M	a	b	C	K	Erodibility Class
1	Hl F	3315	11,20	3	2	0,03	Very Low
2	Hs F	4039	11,19	3	2	0,04	Very Low
3	Kr B	1599	4,28	3	4	0,15	Low
4	Kr D	3390	5,91	3	4	0,23	Moderate
5	Kr F	3937	6,90	3	3	0,21	Moderate
6	Kc D	3771	7,39	3	3	0,18	Low
7	Sw B	3945	3,16	2	4	0,33	Slightly high
8	Sw D	1803	2,95	2	5	0,18	Low
9	Sm D	1759	4,41	3	3	0,14	Low
10	Sm F	1535	4,57	3	3	0,12	Low

Where :: M = (% +% very fine sand dust) x (100 -% clay), a = Organic matter content (%), b = Soil structure Code, c = soil permeability code, K = Soil Erodibility value.

From Table 4 it can be seen that the value of K ranges from 0.02 to 0.33 with very low to slightly high criteria.

3) *Index and slope length (LS)*

LS factor calculation results in each land units of Mangau sub-watershed presented in Table 6.

TABLE VI
LS VALUES FOR EACH OF THE SUB-WATERSHED LAND UNITS MANGAU.

No	Land Unit	Length of slope (m)	Slobe (%)	LS Index
1	Hl F	50	47	24,86
2	Hs F	36	37	13,36
3	Kr B	33	8	0,94
4	Kr D	26	29	7,57
5	Kr F	36	36	12,59
6	Kc D	25	31	8,10
7	Sw B	25	28	6,78
8	Sw D	28	7	0,77
9	Sm D	24	25	5,46
10	Sm F	26	48	18,61

Table 6 shows that the LS highest ones found on protected forest land with steep slopes (HLF). Unit has a slope of land area as large as 62% and as large as a factor of 39.92 LS. Whereas, the LS the lowest ones found in rice field with wavy rim (SWB) with a slope of 7% and the LS factor as large as 0.77. So it can be concluded that the greater the slope of the higher slopes of the size of the LS.

4) *Land use factors (C) and Soil Conservation (P)*

Land use factor (C) and soil conservation measures (P) for each unit can be seen in Table 7

TABLE VII
THE VALUE OF LAND USE AND LAND MANAGEMENT (CP) IN THE SUB-WATERSHED OF MANGAU

No	Land Unit	C Factor	P Factor	C x P
1	Hl F	0,001	1,00	0,0010
2	Hs F	0,001	1,00	0,0010
3	Kr B	0,400	0,04	0,0160
4	Kr D	0,100	0,15	0,0150
5	Kr F	0,400	0,15	0,0600
6	Kc D	0,400	0,15	0,0600
7	Sw B	0,010	0,15	0,0015
8	Sw D	0,010	0,04	0,0004
9	Sm D	0,001	1,00	0,0010
10	Sm F	0,001	1,00	0,0010

From Table 7 it can be seen that the value of CP was highest in smallholder land units with different slope (KrF, and KCD) with the use of agricultural lands with conservation techniques bench terrace construction is 0.06 and the lowest CP values found on land units HLF and HSF with land use and natural forest and secondary forest litter many SmD, SmF with scrub land use (0.001). High value of CP which endanger the sustainability of land and water resources due to land use and conservation techniques will determine the magnitude of the danger of erosion.

5) *Erosion Damage grade*

The result of prediction of erosion in each of land units by USLE methode in Mangau sub Watershed will be presented in Table 8.

TABLE VIII
DANGER LEVEL OF EROSION ON EVERY LAND UNITS IN MANGAU SUB WATERSHED.

No	Land Unit	R	K	LS	CP	A Ton/Ha/Th	Solum depth	TBE
1	Hl F	3494,60	0,03	24,86	0,0010	2,61	Moderate	L
2	Hs F	3494,60	0,04	13,63	0,0010	1,91	Moderate	L
3	Kr B	3494,60	0,15	0,94	0,0160	7,88	Moderate	L
4	Kr D	3494,60	0,23	7,57	0,0150	91,27	Moderate	S
5	Kr F	3494,60	0,21	12,59	0,0600	554,36	Moderate	VS
6	Kc D	3494,60	0,18	8,10	0,0600	305,71	Moderate	VS
7	Sw D	3494,60	0,18	6,78	0,0015	6,39	Moderate	L
8	Sw B	3494,60	0,33	0,77	0,0004	0,36	Moderate	L
9	Sm D	3494,60	0,14	5,46	0,0010	2,67	Moderate	L
10	Sm B	3494,60	0,12	18,61	0,0010	7,80	Moderate	L

Where:
R = Erosivity,
K = Eodibility,
LS = Topography Factor
CP = Crops and management Factors ,
A = Erosion (Ton/Ha/Th) ,
L = light , M = moderate,
S = severe,
VS = Very severe, Solum depth depending on profile description (appendix 18)

Table 8 showed that erosion hazard level are very heavy found on people gardens land with relatively steep slope, followed by a mixture of gardens with hilly slope and people gardens with undulating slope. Where as the other ones have a mild erosion hazard level. According Kasiyani, 1988 cit

Rusman 1999 when connected to a large area with very steep slopes and hilly topography, the rainfall potential for very large devastated. Determination of the total erosion that occurs on every piece of land in sub-watershed Mangau can be done by multiplying the number of actual erosion with the ratio of land units. The result can be seen in Table 9.

TABLE IX
WEIGHTED EROSION PREDICTIONS IN EACH SUB-WATERSHED LAND UNITS ON UPPER MANGAU.

No	Land Unit	A Ton/Ha/Th	Ratio of areas (B)	Area (Ha)	Weight Erosion Predictions (Ton/Ha/Th)
1	Hl F	2,61	0,111	1039	0,29
2	Hs F	1,91	0,092	863	0,18
3	Kr B	7,88	0,078	730	0,61
4	Kr D	91,27	0,217	2023	19,8
5	Kr F	554,36	0,312	2912	172,96
6	Kc D	305,71	0,094	874	28,74
7	Sw D	6,39	0,037	347	0,24
8	Sw B	0,36	0,047	438	0,02
9	Sm D	2,67	0,008	73	0,02
10	Sm B	7,80	0,004	35	0,03
total				9334	222,89

Table 9 shows that the weighted erosion potential in the sub-watershed Mangau is 222.89 tonnes / ha / year.

C. The Tolerated erosion

The results of tolerated erosion is shown in Table 10.

TABLE X
THE VALUE OF TOLERATED EROSION (T) ON EACH UNIT OF LAND IN SUB-WATERSHED OF UPPER MANGAU.

No	Land Unit	KE (mm)	FKT	DE (mm)	UT*) (th)	LPT (mm/ th)	BV (g/ cm3)	T (Ton/ Ha/Th)
1	Hl F	650	1,00	650	300	2	0,76	12,66
2	Hs F	600	1,00	600	300	2	0,85	12,68
3	Kr B	630	1,00	630	300	2	0,80	19,27
4	Kr D	600	1,00	600	300	2	0,80	17,35
5	Kr F	550	1,00	550	300	2	0,80	17,22
6	Kc D	650	1,00	650	300	2	0,78	19,37
7	Sw D	500	1,00	500	300	2	0,95	27,05
8	Sw B	500	1,00	500	300	2	0,84	23,93
9	Sm D	500	1,00	600	300	2	0,62	21,70
10	Sm F	550	1,00	550	300	2	0,79	26,33

Table 10 shows that the tolerated erosion in each land unit ranged from 12.15 tonnes / ha / yr to 27.05 tonnes / ha / yr. The diversity of values that can be tolerated erosion is caused by different factors that influence it, namely: soil depth to layers inhibitors (effective depth), soil depth factor, minimum soil depth for plant, soil age, the rate of soil formation, and soil bulk density.

Land units that have large erosion will require corrective action efforts and soil conservation measures can be determined by comparing the actual erosion with erosion that can be tolerated as can be seen in Table 11.

TABLE XI
COMPARISON OF SOIL EROSION (A) WITH TOLERATED EROSION (T) ON EACH LAND UNIT OF THE SUB-WATERSHED MANGAU.

No	Land Unit	A Ton/Ha/Th	T Ton/Ha/Th	Compare
1	Hl F	2,60	12,66	A < T
2	Hs F	1,90	12,68	A < T
3	Kr B	7,88	18,25	A < T
4	Kr D	87,29	17,35	A > T
5	Kr F	580,76	17,22	A > T
6	Kc D	271,74	19,37	A > T
7	Sw D	6,04	27,05	A < T
8	Sw B	0,35	23,93	A < T
9	Sm D	2,67	21,70	A < T
10	Sm F	7,80	26,33	A < T

Table 11 shows that there are 3 units of land that has a value erosion (A) is greater than tolerated erosion (T), which ones people gardens land with steep slopes (KR F), gardens people and gardens blend with hilly land (KRD and Kc D). That's because no suitably with undulating land use. Therefore be sought alternative land use (C) and soil conservation action (P) the right to apply so obtained value erosion (A) is smaller than the value that can be tolerated rapid erosion (T).

D. Alternative Land Use and Soil Conservation Measures

Alternative land use and the proper conservation measures to be applied in dealing with the magnitude of the erosion can be seen in Table 10.

Table 12 shows that the land unit of people gardens with very steep slopes (Kr Kr D and F) require the alternative of mixture gardens land use with high density and conservation actions of bench terrace with good construction dan tightly ground cover. Units of people gardens with relatively steep slopes (KRD) require the alternative land use of mixture gardens with high density and conservation actions make bench terrace with good construction and land cover tightly.

TABLE XII
ALTERNATIVE LAND USE AND APPROPRIATE CONSERVATION MEASURES AND PREDICTION OF EROSION WILL OCCUR ON SOME OF LAND UNIT IN THE SUB-WATERSHED MANGAU.

No	Land Unit	Alternative land use and appropriate conservation measure	Prediction of erosian that will occur (Ton/Ha/Th)
1	Hl F	Protected forest	2,60
2	Hs F	Secondary forest	1,90
3	Kr B	Tetap	7,88
4	Kr D	C1P1P3	2,32
5	Kr F	C1P1P3	3,87
6	Kc D	C1P1P3	13,58
7	Sw D	Sawahs	0,35
8	Sw B	Sawahs	6,04
9	Sm D		2,67
10	Sm F		7,80

Where:
C1 = Garden mix with high density (C = 0.10),
C2 = Farm mixture with density is (the C = 0.20),
P1 = bench terrace with good construction (P value = 0.04),
P2 = Bench terrace with construction being (P value = 0.15),
P3 = Crop farming with close ground cover (P = .10).

IV. CONCLUSIONS

Based on the results of the prediction of erosion that has been done on the sub-watershed Mangau, Padang Pariaman and Agam District are conclused by

The greatest erosion occurs on smallholder land units with very steep slopes (45-65%) (KrF) or classified as severe erosion hazard levels. While, the smallest erosion occurred

in wetland units with gentle slope (SWB) (7%) or relatively mild levels of erosion.

There are 3 land units have greater erosion than the erosion of the people who tolerated the garden with a rather steep slope (KrD), garden mixed with rather steep slopes (KcD), and their fields with steep slopes (KrF) The other unit has actual erosion smaller than the erosion that can be tolerated.

All smallholder land units with steep slopes (KrF) and their fields with rather steep slopes (KcD) sought alternative land use is high density mixed farms and conservation measures make a bench terrace construction with good ground cover tightly. The next unit croplands mixed with rather steep slopes (KcD) suitable alternative land use is a mixture of high-density garden and patio benches conservation measures make good construction with a dense ground cover.

REFERENCES

[1] Arsyad, S .1989. Koservasi Tanah Dan Air . Penerbit IPB Bogor. 290 Halaman

[2] Asdak . C. 1995. Hidrologi dan Pengelolaan daerah Aliran Sungai. Gadja Mada Universuty press. 521 hal.

[3] Haryanto, E T , P Santoso, dan A Syafrudin .1990. Hidrologi dan Erosi.Lokakarya PembangunanKehutanan Terlanjut- kan . Bandung, 7 - 8 Mai 1990. ,

[4] Mas'ud, A. F (1987) Perencanaan penelitian dan monitoring DAS secara terpadu kemungkinan permasalahannya. Prosiding Lokakarya Hasil Penelitian Hidrologi Dan Erosi Dalam Rangka Pengelolaan Daerah Aliran Sungai. Tanggal 8-10 Desember 1987. Batu Malang. Halaman 205-218. ,

[5] Maas Syarbaini. 1987. Karakterisasi sub daerah aliran sungai Arau I. Kota Madya Padang, Sumatera Barat. Tesis Magister Fakultas Pasca Sarjana Institut Pertanian Bogor.

[6] Saidi, A. 1995. Aliran Permukaan, Sedimentasi dan Faktor-faktor yang Mempengaruhinya Serta Dampaknya Terhadap Degradasi Lahan di Sub DAS Sumani Solok Sumatra Barat. Disertasi Pasca Sarjana Universitas Padjajaran. Bandung. 178 hal.

[7] Saidi, A., I Berd, dan D Fiantis. 2010. Kajian Analisis Longsoran Akibat Gempa Di Kenagarian Tandikek Kecamatan Patamuan Kabupaten Padang Pariaman Sumatra Barat. Disampaikan pada SEMIRATA di Bengkulu Tanggal 23-25 Mei 2010.

[8] Sinukaban, N. 2010. Analisis dan Strategi Perencanaan Pengelolaan Daerah Aliran Sungai (Referensi untuk Pemanfaatan Sumberdaya Alam Secara Berkelanjutan). Lokakarya Forum DAS Kaltim, 27 April 2010, Samarinda.

[9] Suwardjo, dan A. Saefuddin. 1986. Penelitian Konservasi Tanah Dan Air di Daerah Aliran Sungai. Risalah Lokakarya Pola Usaha Tani . Badan Penelitian dan Pengembangan Pertanian. Bogor.

[10] Wischmeier, W H and D D Smith .1978. Predicting rainfall erosion losses. A Guide to Conservation Planning. Supersedes Agriculture Handbook no 282.

[11] Young, A .1989. Agroforestry for Soil Conservation. C A B International. International Council Research in Agroforestry. BPCC Whetons, Exerter.