

## **Assessment of Surface Erosion and Deposition across Different Land Use Types in the Bunga Watershed, Central Sulawesi Province**

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### **Abstract**

This study examines surface erosion and deposition under different land utilization types in the Bunga Watershed, Central Sulawesi Province. The objectives were to analyze the relationship between rainfall and runoff using the ANSWERS model as a basis for estimating erosion and deposition, to evaluate the influence of land utilization types on surface erosion and sedimentation, and to identify spatial distribution patterns through mapping. A survey method was employed to collect primary data, including soil moisture, permeability, texture, solum depth, organic matter content, slope, stream gradient and width, surface flow direction, rainfall intensity, and temperature, while secondary data such as channel roughness coefficients and land use maps were obtained from Landsat imagery interpretation and field observations. Analysis was conducted for each grid element of the ANSWERS model (250 m × 250 m), and spatial patterns were analyzed using Geographic Information Systems (GIS). The results indicate that even relatively low rainfall can generate significant runoff, with variations primarily influenced by soil characteristics, land use types, and slope steepness. Two main typologies were identified: secondary dry forest areas (above 75%), where deposition generally did not occur and maximum erosion reached 51.364 kg/ha/hour, and mixed dryland farming with shrubs (above 30%), where deposition occurred with a maximum rate of 35.291 kg/ha/hour. Spatial mapping revealed scattered erosion and deposition patterns across partially open and vegetated land surfaces; erosion followed an expansion–diffusion (sheet) pattern with an index of  $T = 0.2057$ , while deposition exhibited a relocation–diffusion basal pattern with an index of  $T = 0.2167$ .

**Keywords:** Land utilization type, Surface erosion, deposition, Spatial Distribution, Simulation.

## I. Introduction

Watershed (DAS) critical land is likely to increase due to the rate of erosion and sediment processes at the land surface by human activity and lack of soil conservation measures[2] (Arsyad, S, 1989). Results of research in Indonesia, especially in Central Sulawesi, the problem of erosion, Regional Office of Forestry of Central Sulawesi Province (2007) a total of 1992 amounted to 290 612 tons/ha/yr, 1993 increased to 301,049 tons/ha/yr, 1994 increased to 306,841 tons/ha/yr, in 2000 increased to 327,629 tons/ha/yr, in 2005 increased to 328,949 tons / ha / yr, and in 2014 increased again to 329,949 tons/ha/yr. Meanwhile, land use DAS Bunga, Regional Office of Forestry of Central Sulawesi Province (2007) includes: (1) The forest, consisting of categories: dry forest secondary and limited production forest, vegetation type in to two categories of the forest is dominated by pine trees, rattan, resin (*Agathis*) leda trees (*Eucalyptus deglupta*), mahogany, ebony tree, covering an area of 16,211.34 ha or by 77.70% of the total area of the watershed; (2) Agricultural Land upland mixed shrubs, consisting of categories: coconut groves, cocoas, and mixed farms, covering an area of 739,23ha or 3.54% of the total basin area.

Observations from DAS Bunga, found a land use balance has been disturbed by the activities as a result population changes that are not in accordance with the designation (Amiruddin, 2014). As a sub-system of hydrology, the natural variable components, such as: precipitation, runoff, groundwater, evapotranspiration, humidity, disrupted. Strategies in knowing the erosion and deposition in a watershed, the hydrological model which has distributed each characteristic element of the concept of land-use layout can in known through the model of nonpoint source Areal Nonpoint Source Watershed Environment Response Simulation (ANSWERS) introduced (Beasle *et al*, 1981). Based on the background of the problem, the researchers are interested in doing research titles surface erosion and deposition on the Different Land Utilization Types in DAS Bunga Central Sulawesi province.

This study focused on: (1) the relationship between rainfall with runoff in the DAS Bunga, as a basis to determine the amount of erosion and deposition; (2) how much influence the type of land use on erosion and deposition in the sub-DAS Bunga; (3) how the shape of the spatial distribution patterns of erosion and deposition on an element as a parameter influence land use types, rainfall, runoff, and runoff. Location DAS Bunga be between 119° 52' 16" EL(East

Longitude) until 120° 5' 54" EL and between 0° 57'15" SL(South Latitude) until 1° 8' 3" SL (Amiruddin, 2014). Furthermore, the boundary areas of research are: 1) north to the DAS Konju; 2) east of the DAS Sambitaa, DAS Sumpu, DAS Wempi; 3) west of the DAS Wenondi; 4) south of the river DAS Tingguli and DAS Watunonju. Type of tropical monsoon climate with an average annual temperature between 26.70°C to 28.70°C; Average annual air pressure between 1008.50 to 1011.60 mb; the average annual air humidity between 70.00 to 82.00% and the average duration of 3 hours 17 minutes of rain, heavy rain in the intensity of 73.58 mm 12.50 mm/hour (Amiruddin, 2014).

### Forms Of Geological Das Bunga

Constituent DAS Bunga geological formations from the time of secondary, tertiary, and quaternary sourced from geological maps of 1: 250,000 scale: 1) Review the Geologic map sheets Palu (Sukamto, 1973); 2) Geological map Pasangkayu Sheet (Sukido *et al*, 1993); 3) Geological map of Poso Sheet (Simanjuntak *et al*, 1996), are presented in Table.1.

Table.1. Stratigraphy Framework rock DAS Bunga

Time	Era	Ages		Surficial Deposits	Sedimentary rocks	Intrusive rocks
<b>CAENOZOIC</b>	Quarternary = 0,5-1 million years	Holocene		Qap = Alluvial formations	X	X
		Pleistocene		X	QTms = Celebes Molasa Sarasin and Sarasin or Pakuli Formation	
		Pliocene		X	X	
	Tertiary	Mioce ne = 26 million	Upp er	X	X	Tmg = diorite complex
			Mid dle	X	Kls = Formation Tineba	X

		years	(Lo wer	X	X	X
		Oligocene = 38 million years		X	Metamorphic rocks	X
		Eocene = 58 million years		X		X
		Paleocene = 12 million years		X		X
<b>MESOZOIC</b>		Cretaceous = 127 million years		X	TRjg = Formation Latimojong	km = Complex metamorphic rocks
		Jurassic = 152 million years		X	X	
		Triassic = 182 million years		X	Tmpi= Complex Gumbasa and Wana	

Source: 1. General Introduction to Geology (Simanjuntak *et al*, 1996); 2. Map Geomorphology Palu valley Area, Central Sulawesi, scale 1: 100,000 by Murtolo *et al*, 1994).

## II. Research Methodology

The research methodology is based on several steps, namely: determining the location of the research conducted by purposive sampling, primary and secondary data collection, data analysis and report preparation.

### Geographical Conditions

DAS Bunga landforms of the formation of fluvial origin (F), eg: alluvial fan covering 874.68 hectares or 47.58%, and the formation of origin denudation (D), eg: delegated metamorphic mountain area of 223.10 hectares or 12.14% and delegated metamorphic hilly area of 740.49 hectares or 40.28% (Regional Office of Forestry of Central Sulawesi Province, 2007).

Slopes in the DAS Bunga comprising: a bit bumpy (15-25)% covering an area of 874.65 hectares or 47.58%, hilly (25-40)% covering an area of 740.49 hectares or 40.28%, and mountainous (> 40%) covering an area of 223.14 hectares or 12.14%, (Regional Office of Forestry of Central Sulawesi Province, 2007). Based on soil maps issued by BP-DAS Palu-Poso and semi-detailed soil maps Donggala growing land in the watershed is a complex Bunga Latosol Brown & Litosol (lithic Tropudalf) covering an area of 223.10 or 12.14%, whereas Brown Latosol ( Tropudalf) seluas 1.615,20 ha or 87.86% (Murtolo *et al*, 1994).

### Input Parameters Answers Models

Input parameter models ANSWERS consists of: total porosity (TP), field capacity (FP), the infiltration rate constant state (FC), (Hibbert, 1983), the difference in the rate of infiltration maximum infiltration rate constant (A), the percentage of soil saturation (ASM), and the coefficient of infiltration (P), (De Roo, 1981);(Harto, 1993), as shown in Table 3.

Table.3 Data Input Parameter land in the Watershed Bunga

<i>Kind of soil</i>	TP (%)	FP (%)	FC (mm/hr)	A (mm/hr)	P	DF (mm)	ASM (%)	K
Latosol Brown ( <i>Tropudalf</i> )	47.0	42.0	27.37	15.38	0.60	670.0	60.0	0.70
Complex Latosol Brown & Litosol	44.0	42.0	28.37	19.76	0.60	200.0	80.0	0.10
Kambisol Eutrik ( <i>Eutropept</i> )	32.0	42.0	70.86	30.43	0.65	220.0	70.0	0.41
gray alluvial ( <i>Udifluent</i> )	55.0	0.39	97.12	30.43	0.70	512.0	55.0	0.412

Source: Results of field measurements, Lab analysis. and secondary data, 2015

Land use types of input parameters, including: the volume of potential interception (PIT), the percentage of closure by land use (PER), Manning's constant (N), and the relative erosivitas (C), (Beasley *et al*, 1981);(Douglas, 1968); (Edwards *et al*, 1981), are presented in Table 4

Table 4. Input Parameter Data Type Land use in the DAS Bunga

Land Utilization Type	PIT (mm)	PER (%)	HU (mm)	RC	N	C
Secondary dry forest	1.80	65.0	75.00	0.45	0.15	0.200
Mixed dry land agriculture bush	1.10	60.0	62.50	0.52	0.11	0.300
Paddy	0.65	50.0	62.50	0.55	0.11	0.300
Shrubs	1.75	65.0	75.00	0.37	0.11	0.300
Fields	0.06	60.0	60.00	0.60	0.12	0.010

Source: Results of secondary data analysis, Regional Office of Forestry of Central Sulawesi Province, 2007

### Process Analisis Hidrology Answers Models

ANSWERS model structure based on the hypothesis that each point in the watershed have a functional relationship between the rate of water flow and hydrological parameters. The structure of individual data elements: 1) rows and columns; 2) slope; 3) the direction of flow; 4) rainfall, soils, channels (streams), and land utilization types (De Roo, 1981). The development process hydrological model data ANSWERS (Fig.4) (Bradford *et al*, 1982a); (Bradford *et al*, 1982b).

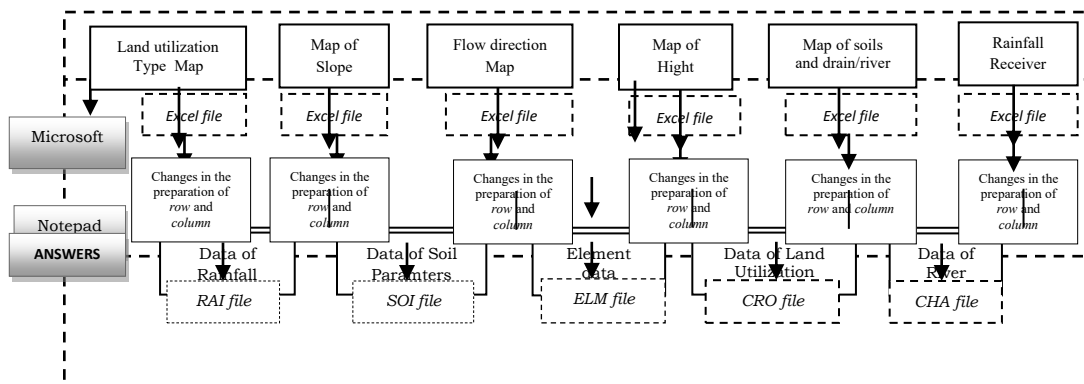


Fig.3. Hydrology Model Data Structure ANSWERS (Beasley *et al*, 1981);(De Roo, 1981).

Charts can be shown, as follows:

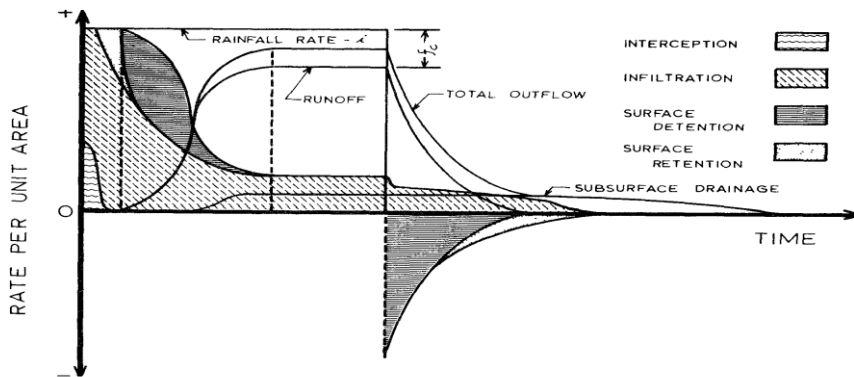
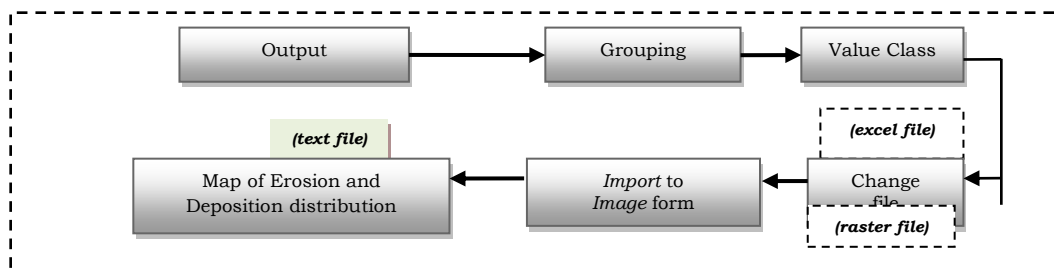


Figure 4. Chart Movement Water flow in each element (Beasley et al, 1981)

### Mapping Spatial Erosion and Deposition

Mapping is done as 250 meters x 250 meters, following, Beasley *et al*, (1981); De Roo, (1981): 1) DEM (Digital Elevation Model) and Flow Direction. Making DEM with Arc View GIS 3.3 software from contour map processing to TIN (Triangulated Irregular Network) form by using hydrology modeling extension; 2) The making of Thematic Map, in the form of: a) map of landform; B) the interpretation of the Earth Map of Indonesia (RBI) digital scale of 1: 50,000, Murtolo *et al*, 1994); C) slope map; D) soil type map; E) map of land use type. Changing output ANSWERS numeric models back into the form of a map or raster data, (Liu *et al*, 2001); (Seyhan, 1977), as shown in the diagram Gambar.4.



Picture. 4. Phase Distribution mapping Erosion and Deposition

### III. Results and Discussion

#### Land Utilization Types Simulation

Comprehensive simulation of the types of land use in the watershed Flowers into several scenarios, are shown in Table 5. and Table 6. the following table:

Table 5. Land Utilization Type Scenario DAS Bunga

Scenario	Land Utilization Types					
	Secondary dry forest (Htn)		Mixed dry land agriculture bush (Plk)		Shrubs (Sbr)	
	Ha	%	Ha	%	Ha	%
Actual	1,448.22	78.78	199.36	10.84	190.69	10.37
Scenario 1	740.33	51.12	21.01	10.54	73.11	38.34
Scenario 2	681.10	47.03	22.21	11.14	79.08	41.47
Scenario 3	540.48	37.32	22.73	11.40	96.62	50.67
Scenario 4	532.94	36.80	23.74	11.91	96.34	50.52

Source: Analysis of 2015

Table 6. Results of Simulation influence land utilization types in the DAS Bunga

Scena rio	Rainfall Intensity (mm/hr)	Run off (mm)	The average loss of land (kg/ha/hr)	Erosion rate max. (kg/ha/hr)	Deposition max (kg/ha/hr)
Actua 1	18.97	0.471	6.939	51.364	35.291
Scena rio 1	18.97	0.241	3.547	26.257	18.041
Scena rio 2	18.97	0.222	3.263	24.156	16.597
Scena	18.97	0.176	2.590	19.169	13.171

rio 3				
Scena	18.97			
rio 4		0.173	2.554	18.902
				12.987

Source: Analysis of 2015

### Effect of Rain Against the flow, erosion, and deposition in the DAS Bunga

Based on analysis of the influence of rainfall, runoff, and the type of land use on erosion and deposition ANSWERS model in DAS Bunga, are presented in Table 7.

Table 7. Data rainfall, flow, erosion and deposition DAS Bunga

Parameters	DAS Bunga
<b>❖ Rain Parameters (mm/day)</b>	
Rainfall Average	8.717
Runoff Average	0.471
<b>❖ Order parameter river network</b>	
Order	1,2,5,6
<b>❖ Geology</b>	
Rock outcrop (ha) (%)	
Metamorphic sandstone, shale, conglomerate	829.6 ha or (45.13%)
Diorite, andesite, Grand diorite	1.001.2 ha or (54.47%)
Conglomerate, Sandstone	7.4 ha or (0.04%)
<b>❖ Geomorphology</b>	
<b>a. Land use Parameter (ha) and (%)</b>	
alluvial fan	874.68 ha or (47.58%)
Metamorphic mountains denudation	223.10 ha or (12.14%)
Metamorphic hills denudation	740.49 ha or (40.28%)
<b>b. Slope Parameter (ha) and (%)</b>	
Rather steep / wavy (15-25)%	874.65 ha or (47.58%)
Steep / hilly (25-40)%	740.49 ha or (40.28%)

Very steep/mountainous (>40%)	223.14 ha or (12.14%)	
<b>❖ Land Utilization Types Parameter (ha) and (%)</b>		
Secondary dry forest	1,448.22 ha or (78.78%)	
Shrubs	190.69 ha or (10.37%)	
Mixed dry land agriculture bush	199.36 ha or (10.84%)	
<b>Average Losing Land</b>	1 kg/ha/hour	
<b>The maximum erosion rate</b>	32.542 kg/ha/hour	
<b>The maximum deposition rate</b>	33.520 kg/ha/hour	
<b>Types</b>	<b>Surface Erosion</b>	Sheet
	<b>Deposition</b>	Basinal
<b>Pattern</b>	<b>Surface Erosion</b>	Disperse
	<b>Deposition</b>	Disperse

Source: Analysis of 2015

### 3.1.3 Map of the spatial distribution erosion and deposition of DAS Bunga

#### a) Map of Erosion

Erosion spatial distribution maps based on the data output ANSWERS model Table 7. The example presented in Figure 5.

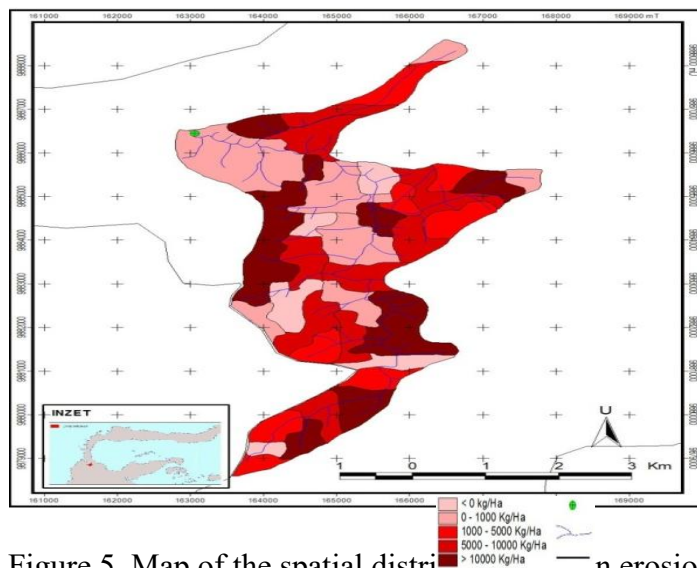


Figure 5. Map of the spatial distribution of erosion to events 1

#### b) Map of Deposition

Deposition spatial distribution maps based on the data output ANSWERS model Table 7.  
The example presented in Figure 6.

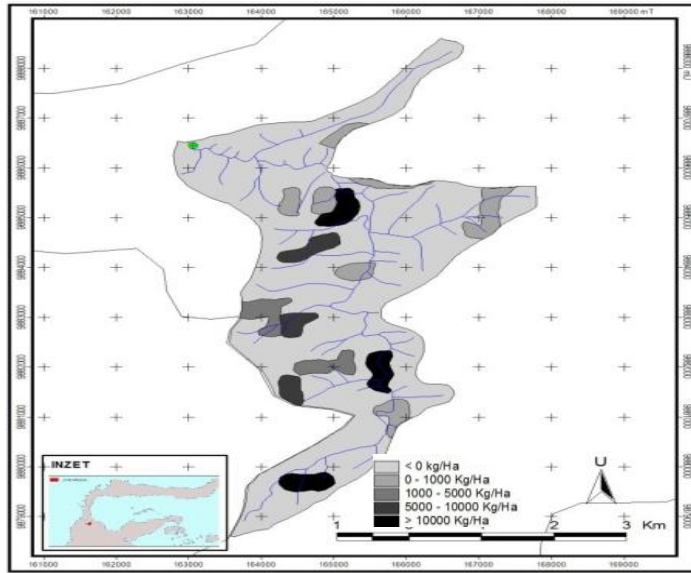


Figure 6. Map of the spatial distribution of deposition for one rainfall event

## Discussion

The results showed that the difference of landforms has been ruled out in the study of changes in land use turned out to have significance in understanding erosion and deposition. Region eroded slope that had been in the know have a linear spatial distribution pattern towards the foot of the slopes is not always true. DAS Bunga landform pattern and river flow patterns the same, which follows the pattern of dendritic. Meanwhile, the spatial distribution pattern of slope in the region eroded surface can thrive, and low region experiencing the erosion deposition surface can also develop multi-basin retrace pattern.

The approach of the spatial distribution which has been based on elements of land is small in a watershed or on special farms, Wischmeier *et al* (1978); Douglas (1968); Ziegler *et al* (2001); Baruti (2004) by itself cannot be used in explaining the phenomenon of complete and perfect for the spatial distribution of spatial approach on slope and precipitation will obviously cause misinterpretation in identifying landforms eroded (Onori *et al*, 2006). The findings in the study show that not all high rainfall and brief with a steep slope to a very steep organized in

spatial linear erosion and deposition. Specific rainfall of moderate intensity long duration and landforms with steep slope not largely organized in a spatial erosion, deposition of patterned scattered with multi-basin type.

Thus landform mountains and hills in the DAS Bunga formed as the mountainous terrain is still going geomorphic processes that power the processes that cause erosion. This process occurs because of the controlling factor that comes from below the earth's crust (Onori *et al.*, 2006) (endogenous power), above the Earth's surface (exogenous force), (Bosch *et al.*, 1982), and force / power of extraterrestrial (extra power terrestrial) (Assouline *et al.*, 2006).

The first controller factor, is a particularly climate rainfall intensity, a higher intensity of rain is 19.18 mm/h (Bung-1); 19.21 mm/h (Bung-2) and 18.63 mm/h (Bung-3), allowing erosion and sedimentation processes take place more intensively, previous studies by (Onori *et al.*, 2006); (Assouline *et al.*, 2006), while the results of the sediment is runoff discharge (Douglas, 1968).

The second factor affecting the erosion process is the soil condition, mainly the humidity factor (ASM), field infiltration capacity in constant state (FC), total porosity (TP), permeability describing soil type, and soil sensitivity to erosion (erodibility = K) Influenced by the texture, structure, and permeability of the soil (Foster *et al.*, 1977); (Seyhan, 1977). Previous studies (Ziegler *et al.*, 2001) have found that vacant soil is left open, potentially forming high surface runoff and accelerating erosion. Douglas (1968) suggested that hilly and mountainous topography resulted in faster surface runoff and surface runoff and also resulted in high sediment yields. Sinukaban *et al.* (1994) suggest that soil moisture is an important factor in the extent of infiltration, surface runoff and the occurrence of surface erosion. Meanwhile, Thornbury (1958) states that the erosion process is influenced by dimensions and density distribution of the valleys, the higher the value of K, the soil becomes more sensitive to erosion (Ziegler *et al.*, 2001).

The third factor affecting the erosion process is the form of land which in this case is the location of the land and the slope in general. Patterns of hilly and mountainous terrain tend to have parallel patterns with rather steep to very steep categories (Thornbury, 1958); (Philips *et al.*, 2004); (Rahim, 2000); (Poerwowidodo, 1999).

The fourth factor that affects the erosion process that includes different types of land use, because of the needs that exist. (Asdak, 2002); (Arsyad, 1989) states, a good soil cover

vegetation such as thick grass or thick bushes will remove the effect of intensity and form of land on erosion.

The proportion of watershed area with secondary dry land forest reaches between (77.25 - 100)%, shrubs / groves reaches  $\geq 5.95\%$  and rice fields  $\geq 11.01\%$ , no age soil loss on average. Furthermore, on the condition of the percentage of land use type, soil type, duration and intensity of the same rain at each occurrence, the average on the lower slope between (15 - 25)%, the average deposition average of 7,847.7 kg/ha High) with a maximum sediment rate of 35,556 kg/ha, elements related to the lower place at the foot of the terraced metamorphic hill slopes, allegedly forming a colluvial fan form.

The findings in this simulation show that there is no significant increase in erosion rate, deposition rate, and significant land loss, when the forest is reduced to shrubs, dry land agriculture, and fields in short and non-permanent brackets, eg : New crop yields, still a good cover of the soil with the litter.

#### **IV. Conclusions and Recommendations**

The conclusion that can be formulated from the results of this study are as follows.

##### **Conclusions related to the rainfall on runoff:**

- a. little rainfall, can potentially generate a large surface flow, such as in very steep slopes and open, so the chances of infiltration and gravity is very small. As a result, runoff be quickly transformed into a runoff. The effect of rain on the surface of the stream may be direct and indirect, direct influence is through the kinetic energy of rain, mainly intensity and diameter of water droplets of rain. The indirect effect is determined through its influence on the growth of vegetation and the flow of runoff from the upper element .;
- b. factors that control to be able to explain the difference in the flow area of research is the factor that turns the soil, such as soil porosity, field capacity, infiltration rate in a constant state, the initial soil moisture, infiltration zone depth, organic matter and soil erodibility. In connection with that, the factor of land use has changed, such as the percentage area of land use types, erodisivity relative, and the coefficient of the ground surface;
- c. by runoff, the study area can be characterized by two categories. First, for a little rain to a large flow is the order of the channel network/stream 1, 2 and 5, 6 in general, and is a

continuation of a network of order 3 and 4 of the sub-sub-basins on it, it is found in the DAS Bunga.

2. Conclusions related types of land use on erosion and deposition:

- a. not all types of land use affect the erosion and deposition. Type of dry land farming extensive mixed shrub and tree density above 30%, eroding the surface of the sheet type and the type of basinal deposition ranging from high to very high, found in the watershed Bunga. In connection with that, the type of dry forest land use extensive secondary and density above 65% and shrubs / bush and the fields above 75% does not happen erosion and deposition;
  - b. factors that control which may explain the differences in surface erosion and deposition in the study area is the type of land use, particularly secondary dry forest and the slopes;
  - c. by function type of land use on erosion and deposition, the study area can be categorized into four, namely: (1) protect the soil surface from the impact of rainwater; (2) reducing the speed and volume of runoff; (3) has the ability to hold soil particles in place through the root system and litter; (4) has the ability to maintain stability in the soil's capacity to absorb water so it does not happen to lose ground. In connection with the deposition depends on the magnitude of erosion and transport element particles eroded soil. Therefore, deposition usually vary following the physical characteristics of the watershed. Statistical test results depending paired ANSWERS models with field measurements obtained, deterministic coefficient value ( $R_2$ ) of 0.989 and a correlation coefficient ( $R$ ) 0.994 as well as different test paired  $t = 1.86 < t_{table} = 2.26$ , so the model is quite good at predicting ANSWERS the volume of runoff and deposition in the study area.
3. The results of the mapping of the ANSWERS model output, obtained dispersed spatial distribution pattern occurs on the land surface land element is partially open and partially covered by a canopy of trees, grass, litter of leaves and twigs rather tight with up to several centimeters thick: (a) diffusion-type surface erosion expansion with pattern sheets on landforms hills and mountains with slopes ranging experience denudation rather steep to very steep; and (b) deposition of type diffusion relocation with basinal pattern on alluvial fans and hills landform suffered denudation generally found on the lower slopes of start ramps up very steep.

## Recommendations

Some of the suggestions submitted are:

1. The results of this study should be used as a guide in determining the location of effective erosion surfaces, especially the type of splash erosion, sheet, gully and ditch. Its location can be instantly viewed and measured in the field based on data obtained from the model output ANSWERS.
2. The area surface runoff and erosion, especially erosion of the data sheet ANSWERS model output, then the management can be done by making the correct terraces, planting vegetation that can serve as a barrier raindrops can hit directly into the ground. Furthermore, the area of runoff and erosion surfaces are on the slopes of > 40%, preferably reforested because of the sloping land and slope (25-40)% is hilly lands have a high risk of surface erosion.
3. Further studies and the magnitude of the location of the land lost due to erosion on lands that are effective and intensive have been made terraces by locals to capitalize on data from existing research results.

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