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A STUDY OF EROSION POTENTIAL IN ORDER TO REHABILITATE LAND AND FOREST IN AMANDIT CATCHMENT, SOUTH KALIMANTAN

Muhammad Ruslan[1], Abdi Fithria[2], Setia Budi[3] and Syam'ani[4]
Forestry Faculty, Lambung Mangkurat University
Banjarbaru City, South Kalimantan, Indonesia

ABSTRACT

In planning the land and forest rehabilitation (LFR) activities in a watershed, the problems of erosion potential (EP) should be taken into account. The objective of this study was to analyze the characteristics of erosion potential and the directives of land and forest rehabilitation. This study was conducted in the Amandit catchment, Hulu Sungai Selatan Regency, South Kalimantan Province. Data were collected using observation and interviews. They were analyzed with empirical equation models, spatial modeling in determining the erosion potential, content analysis and tabulation matrix. The results showed that in the upstream portion of the Amandit catchment, the area of EP (Moderate, Severe and Very Severe) was 163,14.95 Ha larger than the area of EP (Very Light and Light) 5,352.42 Ha. So were in the midstream portion of the Amandit catchment, the area of EP (Moderate, Severe and Very Severe) was 20,334.55 Ha larger than that of EP (Very Light and Light) 7,920.89 Ha. By contrast, in the downstream portion of the Amandit catchment, the area of EP (Moderate, Severe and Very Severe) was 1,661.41 Ha smaller than that of EP (Very Light and Light) 63,858.11 Ha. The total areas in the directives of land and forest rehabilitation in the Amandit catchment at the Upstream, Midstream, and Downstream portions were 16,314.55 Ha, 20,334.53 Ha and 1,661.41 Ha, respectively. The directives of land and forest rehabilitation in the three portions of the Amandit catchment were: 1) Natural Forest Succession, 2) Reforestation Pattern, 3) Agroforestry Pattern with Food Crops, 4) Afforestation or Industrial Timber Plantation (ITP)/ Community Forest, 5) Maintaining mixed-species plantation and rejuvenation added with the Multi Purpose Tree Species (MPTS), 6) Maintaining Plantation Forest with ITP pattern with fast growing tree species, 7) Maintaining the Plantation Forest with ITP pattern and community forest with fast growing tree species, 8) Maintaining the settlement area with the development of garden plants and 9) Maintaining the rice fields with the development of bench terraces.

Keywords: Erosion Potential, Land and Forest Rehabilitation

I. INTRODUCTION

A. Background

The Amandit catchment is part of the Negara sub-watershed which is included in the Barito watershed, South Kalimantan Province, which is mostly located in Hulu Sungai Selatan (HSS) Regency and in a small part of Tapin Regency, with a total area of 117,920 Ha. According to BP DAS Barito[3] in HSS regency are there uncritical, potential critical, rather critical, critical, and very critical areas of 13,724.0 ha, 54,819.6 ha, 84,904.2 ha, 13,106.2 ha, and 2,818.0 ha, respectively. The data of critical levels of the land were based only on the administrative area boundaries. They should have been based on ecological regions (sub-watersheds/ catchments). The slopes of topography that affect erosion vary greatly, from the flat slopes (0% - 8%) to the very steep ones (> 40%). The land uses in the upstream and midstream portions of the Amandit catchment are for dryland agriculture, fields, plantations, and other land Suez[9].

If the land in the Amandit catchment is utilized with paying less attention to the principles of soil and water conservation, it will tend to change the forest vegetation into shrubs and reeds. Such conditions will increase the land degradation such as soil erosion and flooding in rainy season. Soil erosion brought about by the surface runoff due to the high slope will increase sedimentation and silting of rivers or lakes. For example, in a forest with its land covers of shrubs and reeds, when the estimated erosion and soil solum is known, the erosion potential (EP) can be determined. The data of EP are very needed in determining the land critical levels. The efforts carried out to minimize the land degradation with EP indicators can be done with land and forest rehabilitation activities. It is necessary to find out which part of the watershed, forest function and land cover has moderate, severe, or very severe EP in order to determine the appropriate land and forest rehabilitation (LFR) activities to be done by people in a watershed, such as reforestation, natural forest succession, agroforestry, afforestation, mixed-species plantation and dryland agriculture.

B. Problem Formulation

The issue of land critical level is closely connected with the erosion potential. The factors affecting the erosion potential are rainfall, slope, soil erodibility, vegetation, and soil management. In order to meet the objectives/targets of land and forest rehabilitation, the erosion potential (EP) in each location of watershed, forest and land cover should be determined (whether it is Moderate, Severe and Very Severe). It will also help to determine the directives of land and forest rehabilitation (LFR) activities in accordance with the condition of each targeted location.

Based on the explanations stated above, the problems in this study can be formulated as follows:

1. Whether the erosion potentials occurring now belong to the class of Moderate, Severe and Very Severe, and whether they can be considered in the LFR activities.
2. What are the directives of LFR activities based on the erosion potential in point 1 to be applied in the Amandit catchment.

From the description of the problems mentioned, it is very urgent to carry out a study entitled "A Study of Erosion Potential in order to Rehabilitate Land and Forest in Amandit Catchment, South Kalimantan."

C. Objectives

The objectives of this study are as follows:

1. Analyzing the characteristics of erosion potential (EP) at various regional functions and land units.
2. Determining, based on the first objective, the directives of Land and Forest Rehabilitation in the upstream, midstream, and downstream portions of the Amandit catchment.

II. Study Methods

A. Place and Time

This study was conducted in the Amandit catchment, Hulu Sungai Selatan Regency, South Kalimantan Province. The study location was divided into three, namely the Upstream, Midstream, and Downstream portions of the Amandit catchment (Appendix 1).

The study that was carried out in 2014 required 8 (eight) months to accomplish, from preparation, data collection, data processing, report drafting, report revision to final report reduplication.

B. Objects, Equipment and Materials

The objects observed in this study were some components of biophysical sub-systems such as soil, land cover vegetation and rainfall.

The materials included plastic bags and some maps closely linked to the study problems. The equipment used was GPS Brand Garmin, Clinometer, Compass, Camera, Land Drilling Machine, Ring Sample and Tally Sheet, as well as a set of computer and a map processing program/Arc GIS 10.

C. Data Collection Procedures

1. Preparation of Spatial Data of Land Unit

Broadly speaking, the stages in the preparation of spatial data of land unit were to overlay the map of soil types and the map of slope classes. The map of the land unit was overlaid again with the map of forest zone and land cover until we got the map of the land unit in the Upstream, Midstream, and Downstream portions of the Amandit catchment.

2. Primary data and secondary data

The required secondary data were: a) General description of the study site, b) Rainfall data in the last 10 years, c) Landsat image and Spot Image Maps, Topographic Map (RBI, JOG), Land Use Map, Land Type Map, Slope Class Map and Land Cover Map, d) Land and Forest Zone Map.

The primary data were collected through direct observation from the field, consisting of a) vegetation/ land cover, which were the groups of land covers in the forms of secondary forest, plantation forest, plantation, shrub, and field, and b) data of some physical properties of soil, including the structure, texture (sand, silt, clay), very fine sand content and permeability, and the chemical properties of the soil such as organic matter content. The steps taken in the collecting process of primary data for the land cover observation and the soil sampling on each unit of defined land were implemented in accordance with specific procedures. Data of soil samples were analyzed in the laboratory.

D. Data Analysis

1. Erosion Potential (EP)

a. Calculation of Erosion Amount (A)

The estimated erosion as one of the bases for determining the Erosion Potential (EP) can be calculated with the USLE formula [6].

$$A = R.K.L.S.C.P.0.61$$

Notes:

A = Amount of erosion (t/ha/year), R = Rainfall erosivity (mj.cm/ha/hour-/year), K = Soil erodibility (tons ha.hour/ha/mj.cm), L = Slope length (m), S = Slope (%), C = Crop management, and P = Soil conservation.

b. Assessment of Erosion Potential

The assessment of erosion potential (EP) was done by grouping the results of erosion calculation (A) into the EP table. The results of the analysis of the EP table was connected with the soil solum using Table Matrix EP[11], so that we got some classes of EP, which can be seen in Table 1.

Table 1 Matrix of Erosion Potential

Soil Solum (cm)	Erosion potential (EP) I	II	III	IV	V
	Erosion (ton/ha/year) < 15	15 - < 60	60 - < 180	180 - 480	> 480
	Erosion potential (EP)				
Deep (>90)	0 – VL	I – L	II – M	III – S	IV – VS
Moderate (> 60 – 90)	I – L	II – M	III – S	IV – VS	IV – VS
Shallow (30 – 60)	II – M	III – S	IV – VS	IV – VS	IV – VS
Very shallow (< 30)	III – S	IV – VS	IV – VS	IV – VS	IV – VS

Source: Ditjen RRL (1998)[11].

Notes: 0-VL = Very Light; I-L= Light; II-M = Moderate; III-S = Severe; and IV-VS = Very Severe.

2. Directives of Land and Forest Rehabilitation (LFR)

The directives of LFR were analyzed and elaborated using a tree diagram based on the following factors: a) Erosion Potential; the activities selected for the directives of LFR were EP Moderate (II-M), Severe (III-S) and Very Severe (IV-VS); whereas EP Very Light (0-VL) and Light (I-L) only needed maintenance in order to maintain the preservation aspect of the land and forest, b) the portions of the catchment (Upstream, Midstream, and Downstream), c) Forest Zone, and d) Land Cover. The technologies in the directives of LFR were vegetative methods and civil engineering of soil and water conservation.

III. RESULTS AND DISCUSSION

A. Erosion potential (EP)

From the results of field observations analyzed using Matrix Table of EP by combining the class data of erosion potential and soil solum, the EP at various levels on a variety of forests and land covers was obtained. The results can be seen in Appendix 2.

1. Erosion Potential (EP) in Upstream Portion of Amandit Catchment

The data recapitulation of the erosion potential (EP) areas in forest zone (FZ) in the forms of Mount Kentawan Nature Reserve (MKNR), Protected Forest (PF), Production Forest (PDF) and Other Land Use (OLU) and a variety of land covers (LC) in the upstream of the Amandit catchment can be seen in Table 2.

Table 2. Data Recapitulation of EP Area in Upstream Portion of Amandit Catchment

No.	FZ	LC	(0-VL)	(I-L)	(II-M)	(III-S)	(IV-VS)	Total LC	Total FZ
1	MKNR	SR	0.00	1.62	0.13	3.18	49.51	54.44	54.44
		SR	0.00	450.7	1110.32	3518.77	6374.31	11,454.10	
2	PF	DA	0.00	0.00	19.98	18.91	96.63	135.52	16,587.42
		NF	90.75	4657.73	249.32	0.00	0.00	4,997.80	
3	PDF	SR	0.00	58.88	465.84	516.69	548.42	1,589.83	1,589.83
4	OLU	SR	0.00	89.07	846.49	1467.34	718.94	3,121.84	3,435.68
		DA	0.00	3.67	12.1	2.72	295.35	313.84	
	Total		90.75	5,261.67	2,704.18	5,527.61	8,083.16	21,667.37	21,667.37

The erosion potential (EP) area of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) in the forest zones of MKNR, PF, PDF and the land covers of Shrubs (SR), Natural Forest (NF) and

Dryland Agriculture (DA) was 16,314.95 ha (75.30%), becoming the target of LFR activities, larger than the EP area of Very Light (0-VL) and Light (I-L) which was 5,352.42 ha (24.70%).

2. Erosion Potential (EP) in Midstream Portion of Amandit Catchment

The data recapitulation of erosion potential (EP) areas in the forest zones (FZ) in the forms of Mount Kentawan Nature Reserve (MKNR), Protected Forest (PF), Production Forest (PDF) and Other Land Use (OLU) and a variety of land covers (LC) in the midstream portion of the Amandit catchment can be seen in Table 3.

Table 3. Data Recapitulation of EP areas in Midstream Portion of Amandit Catchment

No.	FZ	LC	(0-VL)	(I-L)	(II-M)	(III-S)	(IV-VS)	Total LC	Total FZ
1	MKNR	SR	0.00	1.35	2.56	11.66	168.03	183.60	183.60
		SR	0.00	399.25	198.08	916.10	3381.57	4,895.00	
		DA	0.00	86.12	40.04	194.51	925.46	1,246.13	
2	PF	MSP	105.94	0.00	0.00	0.00	208.94	314.88	6,782.70
		PLF	0.00	0.00	0.19	0.00	227.20	227.39	
		OL	0.00	0.00	99.30	0.00	0.00	99.30	
		OL	0.00	0.00	341.66	118.25	0.00	459.91	
		SR	0.00	1289.51	1070.68	844.29	2123.40	5,327.88	
3	PDF	DA	0.00	447.53	84.04	257.80	404.16	1,193.53	10,614.01
		MSP	575.08	849.04	416.55	425.62	765.16	3,031.45	
		PLF	68.38	199.00	71.99	91.25	170.62	601.24	
		SR	0.00	1825.00	870.24	1154.76	2449.31	6,299.31	
		DA	0.00	1071.87	334.76	264.10	998.81	2,669.54	
4	OLU	MSP	764.39	174.90	123.30	0.00	98.87	1,161.46	10,675.13
		OL	0.00	0.00	259.35	3.24	0.00	262.59	
		PLF	0.00	0.30	8.77	14.93	195.00	219.00	
		F	63.23	0.00	0.00	0.00	0.00	63.23	
Total			1,577.02	6,343.87	3,921.51	4,296.51	12,116.53	28,255.44	28,255.44

The erosion potential (EP) area of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) in the forest zones (MKNR, PF, PDF, OLU) and in the land covers in the forms of Shrub (SR), Natural Forest (NF) and Dryland Agriculture (DA) was 20,334.53 ha (72.13%), greater than the EP area of Very Light (0-VL) and Light (I-L), 7,920.89 ha (28.10%).

3. Erosion Potential (EP) in Downstream Portion of Amandit Catchment

The data recapitulation of erosion potential (EP) areas in the forest zone (FZ) in the forms of Mount Kentawan Nature Reserve (MKNR), Protected Forest (PF), Production Forest (PDF) and Other Land Use (OLU), and a variety of land covers (LC) in the downstream portion of the Amandit catchment can be seen in Table 4.

Table 4. Data Recapitulation of EP Areas in Downstream Portion of Amandit Catchment

No.	FZ	LC	(0-VL)	(I-L)	(II-M)	(III-S)	(IV-VS)	Total LC	Total FZ
1	KLDB	SR	0,00	10,08	0,00	0,00	0,00	10,08	10,08
2	PF	SR	0,00	0,55	0,00	74,48	92,49	167,52	167,52
3	PDF	SR	0,00	19,35	0,00	33,76	2,21	55,32	105,67
		DA	0,00	44,46	0,00	0,03	5,86	50,35	
		SR	0,00	35.005,70	206,56	205,40	486,98	35.904,64	
4	OLU	DA	0,00	968,36	0,00	159,97	220,64	1.348,97	65.236,25
		MSP	4.525,66	0,06	100,17	1,25	0,00	4.627,14	

	PLF	0,00	0,25	0,00	0,00	0,00	0,25	
	STM	0,00	1.304,62	1,04	0,00	0,00	1.305,66	
	F	21.976,41	2,61	2,51	68,06	0,00	22.049,59	
Total		26.502,07	37.356,04	310,28	542,95	808,18	65.519,52	65.519,52

The erosion potential (EP) areas of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) in the forest zones (KLDB/ Danau Bangkau protected area, PF, PDF) and the land covers in the forms of Shrub (SR), Plantation Forest (PLF), mixed-species plantation (MSP), Dryland Agriculture (DA), Settlement (STM) and Fields (F) was 1,661.41 ha (2.54%), smaller than the EP areas of Very Light (0-VL) and Light (I-L), 63,858.11 ha (97.46%).

From the data distribution of EP areas in the three portions of the Amandit catchment, the EP areas of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) in the upstream and midstream of the Amandit catchment were larger than the EP areas of Very Light (0-VL) and Light (I-L) while in the downstream portion of the Amandit catchment was the opposite; the EP areas of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) were smaller than the EP areas of Very Light (0-VL) and Light (I-L).

Such condition was suspected due to the effects of land covers and topographic slopes. In the upstream and midstream portions of the Amandit catchment, whose land cover was dominated with shrubs and topography of relatively little steep (15%-25%) and steep (25%-40%), could cause the surface run off and high erosion. This is in accordance with the opinion of Badaruddin[8], stating that in the land cover of shrubs, the index of erosion potential were relatively high, compared to the land covers of forests and plantations. Moreover, according to Ruslan[4] in his study on the Riam Kanan watershed, the composition of land use in sub-watersheds/watersheds dominated reeds and shrubs had the erosion potential (EP) ranging between Moderate (S) to Very Severe (VS). The topography in the downstream portion of the catchment was dominated with flat slopes (0% - 8%) and gentle slopes (8% - 15%) and classified in the soil solum (> 90 cm), swampy and peaty. In the areas whose slopes are flat and gentle, the rate of runoff will be slower than the areas whose slopes are steep and very steep. As a result, the erosion or erosion potential that will occur is small. This is in accordance with the opinion of Herawati[10], in the environment of watershed; the erosion rate is controlled by the speed of water flow and sediment properties.

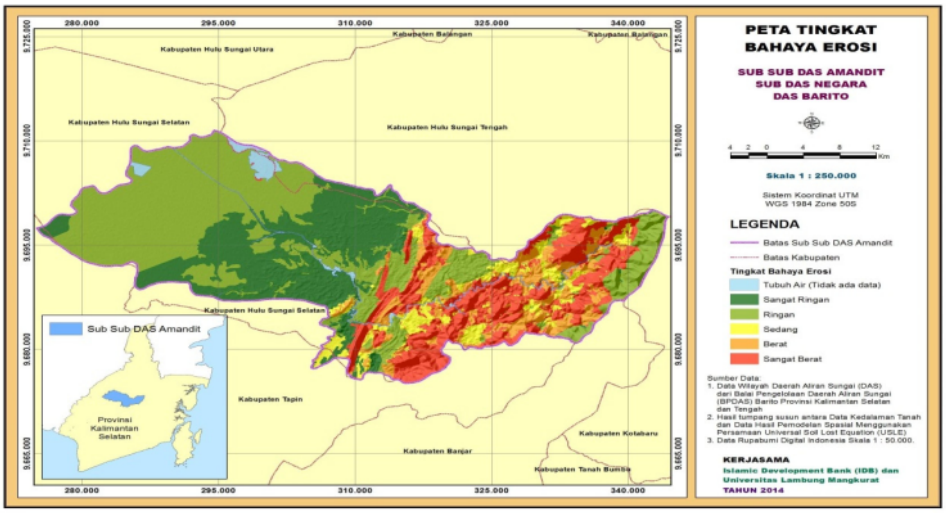

Figure 1. A map of erosion potential in upstream, midstream, and downstream portions of Amandit catchment.

Based on the Erosion Potential data in Table 2, Table 3 and Table 4, the recapitulation of Erosion potential (EP) can be made for the three portions of the Amandit catchment for various forest zones, and land covers. The results are presented in Table 5.

Table 5. Data of Area and Percentage of EP in Upstream, Midstream, Downstream Portions of Amandit Catchment

EP Class	Amandit Catchment							
	Upstream Portion		Midstream Portion		Downstream Portion		Amount	
	Ha	%	Ha	%	Ha	%	Ha	%
Very Light (0-VL)	90.75	0.08	1,577.02	1.37	26,502.07	22.96	28,169.84	24.40
Light (L)	5,261.67	4.56	6,343.87	5.50	37,356.04	32.36	48,961.58	42.41
Moderate (M)	2,704.18	2.34	3,921.51	3.40	310.28	0.27	6,935.97	6.01
Severe (S)	5,527.61	4.79	4,296.51	3.72	542.95	0.47	10,367.07	8.98
Very Severe (VS)	8,083.16	7.00	12,116.53	10.50	808.18	0.70	21,007.87	18.20
Total	21,667.37	18.77	28,255.44	24.48	65,519.52	56.76	115,442.33	100.00

The rate of Erosion Potential (EP) distribution can be specified, ranging from class of Very Light (0-VL), Light (I-L), Moderate (II-M), Severe (III-S) to Very Severe (IV-VS), resulting in a map shown in Figure 1.

A. Directives of Land and Forest Rehabilitation (LFR)

The elaboration in order to select and determine the directives of LFR has considered not only the factors of EP and the portions of the Amandit catchment but also several other factors like Forest Zone and Land Cover as described in the Study Methods. The LFR activities used vegetative methods and civil engineering of soil and water conservation. The results of the elaboration of the directives are as follows: 1) Natural Forest Succession was implemented in the upstream and midstream portions of the Amandit catchment for the Forest Zone (FZ) of MKNR and the land cover (LC) of Shrub (SR), 2) Reforestation Pattern was implemented in the upstream, midstream, and downstream portions of the Amandit catchment with FZ of PF, PDF and OLU and LC of SR, Open Land (OL) and Natural Forest (NF), 3) Agroforestry Pattern with food crops was carried out in the upstream, midstream, downstream of the Amandit catchment with FZ of PF, PDF and OLU, and LC of Dryland Agriculture (DA), 4) Afforestation or industrial timber plantation (ITP)/Community Forestry was held in the midstream and downstream portions of the Amandit catchment with FZ of OLU and LC of SR and OL, 5) Maintenance and rejuvenation as well as using Multi Purpose Tree Species (MPTS) were carried out in the upstream, midstream, downstream of the Amandit catchment with FZ of PF, PDF and OLU and LC of mixed-species plantation (MSP), 6) Maintenance of ITP pattern and use of fast growing tree species were carried out in the midstream portion of the Amandit catchment with FZ of PF and PDF and LC of Plantation Forest (PLF), 7) Maintenance and reforestation as well as using Multi Purpose Tree Species were implemented in the upstream, midstream, and downstream portions of Amandit catchment with FZ of PF, PDF and OLU, and LC of mixed-species plantation (MSP), 8) Maintenance of ITP pattern and use of the fast

growing tree species were carried out in the downstream portion of the Amandit catchment with FZ of OLU and LC of Settlement (STM), 9) Maintenance and use of bench terraces.

From the results of EP analysis (Appendix 2) using the analysis approach and the elaboration of the LFR directives as described above, the areas and types of activities from the LFR directives in the upstream, midstream, and downstream portions of the Amandit catchment can be sorted and described, as the following.

1. Directives of LFR in the upstream portion of the Amandit catchment

Recapitulation of directives of LFR or Land Use in the upstream portion of the Amandit catchment for EP of Moderate (M), Severe (S) and Very Severe (VS) in protected forest (PF), Mount Kentawan Nature Reserve (MKNR), Protected Forest (PF), Production Forest (PDF) and other land uses (OLU) at various Land Covers (LC) can be seen in Table 6.

Table 6. Directives and Codes of Land and Forest Rehabilitation in Upstream Portion of Amandit Catchment

No.	Directives of LFR	Code	FZ	LC	Area (Ha)	Amount	
						Ha	%
1	Natural Forest Succession	D	MKNR	SR	52.82	52.82	0.32
2	Reforestation Pattern	B	PF	SR	11,003.40	15,816.44	96.94
			PF	NF	249.32		
			PDF	SR	1,530.95		
			OLU	SR	3,032.77		
3	Agroforestry Pattern with Food Crops	E	PF	DA	135.52	445.69	2.73
			OLU	DA	310.17		
	Total				16,314.95	16,314.95	100.00

Notes: LC in the forms of SR = Shrubs, DA = Dryland Agriculture, and NF = Natural Forest

From the data in Table 6, the directives of LFR in the form of Natural Forest Succession of 52.82 ha (0.32%) was held in MKNR and in land cover (LC) of Shrub (SR). Reforestation pattern covering 15,816.44 ha (96.94%) was held in PF, PDF and OLU and in LC of SR and NF. Agroforestry pattern with food crops of 445.69 ha (2.73%) was held in PF and OLU and in LC of DA.

It is expected that with Reforestation Pattern in the land cover dominated with shrubs and located in Protected Forest, it can lower the rate of erosion because the role of forest vegetation canopy can protect the soil from the kinetic energy of rainfall and can reduce surface runoff due to their forest vegetation litter and improved soil physical properties. This is in accordance with the opinion of Zhang, *et al.*[7], and Badaruddin[8], the use of the land with forest vegetation will provide a more significant impact on erosion and sediment than other factors, such as climate, soil characteristics and topography.

2. Directives of LFR in the Midstream Portion of the Amandit Catchment

Recapitulation of the directives of LFR or Land Use in the midstream portion of the Amandit catchment for EP of Moderate (M), Severe (S) and Very Severe (VS) in the forest zones of Mount Kentawan Nature Reserve (MKNR), Protected Forest (PF), production forest (PDF) and other land uses (OLU) at various Land Covers can be seen in Table 7.

Table 7. Directives and Codes of Land and Forest Rehabilitation in Midstream Portion of Amandit Catchment

No.	Directives of LFR	Code	FZ	LC	Area (Ha)	Amount (Ha)	Amount (%)
1	Natural Forest Succession	D	MKNR	SR	182.25	182.25	0.90
2	Reforestation Pattern	B	PF	SR	4,495.75	9,093.33	44.72
			PF	OL	99.30		
			PDF	SR	4,038.37		
			PDF	OL	459.91		
3	Maintenance and rejuvenation as well as added with Multi Purpose Tree Species (MPTS)	A	PF	MSP	208.94	2,038.44	10.02
			PDF	MSP	1,607.33		
			OLU	MSP	222.17		
4	Afforestation or Industrial Timber Plantation/ Community Forest	C	OLU	SR	4,474.31	4,736.90	23.29
			OLU	OL	262.59		
5	Agroforestry Pattern with Food Crops	E	PF	DA	1,160.01	3,503.68	17.23
			PDF	DA	746.00		
			OLU	DA	1,597.67		
6	Maintenance with Industrial Timber Plantation Pattern with Fast Growing Tree Species	F	PF	PLF	227.39	561.25	2.76
			PDF	PLF	333.86		
7	Maintenance with Industrial Timber Plantation Pattern and Community Forest with fast growing tree species	G	OLU	PLF	218.70	218.70	1.08
	Total				20,334.55	20,334.55	100.00

It can be inferred from the data in Table 7 that the directives of LFR that could be carried out were seven directives. The Natural Forest Succession of 182.25 ha (0.90%) was held in MKNR. It was important to be done in order to preserve the area of MKNR because its dominant land cover was SR. The reforestation pattern, the largest pattern of 9,095.33 ha (44.72%), was held in PF and PDF, in the land covers of SR and OL, followed with afforestation or Industrial Timber Plantation of 4,736.90 ha (23.29%) and Agroforestry Pattern with Food Crops of 3,503.68 ha (17.23%) held in PF, PDF and OLU in the land cover of DA. Mixed-species plantation was maintained and rejuvenated and added with multi-purpose tree species of 2,038.44 ha (10.02%). It is expected that

the directives of LFR described above can improve the carrying capacity of the land in the midstream portion of the Amandit catchment.

The LFR activities in the forms of reforestation pattern, industrial timber plantation and reforestation prioritizing the planting of trees would be more effective to protect the soil from the kinetic energy of rainfall and to reduce runoff so that the erosion would be lower. The denser the vegetation, the more effective the prevention from erosion. This is consistent with the results of Badaruddin's study[8] in the Kusambi sub-watershed in Tanah Bumbu Regency, stating that the erosion and the rate of erosion can be minimized through the mechanism of forest vegetation (canopy layer and litter on the forest floor) in influencing erosion and runoff. Moreover, Ruslan[4], Asdak[2] and Arsyad[1] explain that the forest vegetation can reduce the surface run off and erosion, due to: a) the interception of tree canopy and litter on the forest floor, and then the kinetic energy of rainfall will be reduced so that a blow against the soil will be decreased, b) forest vegetation will reduce runoff and destructive power of water, c) effect of roots of forest vegetation, humus and biological soil activity towards the stability of soil structure and soil porosity, and d) transpiration of forest vegetation can reduce soil water saturation, thus the amount of water infiltrated into the soil becomes greater and the runoff will be small, resulting in lower erosion.

3. Directives of LFR in Downstream Portion of Amandit Catchment

Recapitulation of the directives of LFR or Land Use in the downstream portion of the Amandit catchment for EP Moderate (M), Severe (S) and Very Severe (VS) in the forest zones of protected forest (PF), Production Forest (PDF) and other land use (OLU) in various Land Covers (LC) is presented in Table 8.

Table 8. Directives and Codes of Land and Forest Rehabilitation in Downstream Portion of the Amandit Catchment

No.	Directives of LFR	Code	FZ	LC	Area	Amount	
					(Ha)	(Ha)	(%)
1	Reforestation Pattern	B	PF PDF	SR SR	166.97 35.97	202.94	12.21
2	Afforestation or Industrial Timber Plantation/Community Forest	C	OLU	SR	898.94	898.94	54.11
3	Agroforestry Pattern with Food Crops	E	OLU PDF	DA DA	380.61 5.89	386.50	23.26
4	Maintenance and Rejuvenation as well as added with Multi Purpose Tree Species (MPTS)	A	OLU	MSP	101.42	101.42	6.10
5	Maintenance and Development of garden plants	K	OLU	STM	1.04	1.04	0.06
6	Maintenance and Usage of Bench Terraces	L	OLU	F	70.57	70.57	4.25
	Total				1,661.41	1,661.41	100.00

In the downstream portion of Amandit catchment, the directives of LFR can be carried out as many as six directives. The directives of LFR mostly implemented were afforestation or Industrial Timber Plantation/Community Forest of 898.94 ha (54.11%) in OLU and in land cover of SR, then followed by the Agroforestry pattern with food crops of 386.50 ha (23.26%) implemented in PDF and OLU in the land covers of DA and reforestation covering 202.94 ha (12.21%) which was held in Protected

Forest and Production Forest in the land cover of SR. The community members have more opportunity to use the land in the other land use especially for Agroforestry, Plantation and Dryland Agriculture with regard to the principles of conservation of soil and water so that the soil degradation or damage can be reduced. The settlement area was developed along with garden plants (food crops, medicines and fruits) to improve public opinion. Especially for the fields located on a gentle slope and a bit steep slope, it is advisable to make bench terraces.

The directives of the land use, such as Agroforestry Pattern, Plantation and Dryland Agriculture and Settlement are the existing residential lands that provide ecological function and economic benefits. This is in accordance with the opinion of Arsyad[1] which states that ecologically agroforestry system is very helpful to maintain the quality of the land. The vegetation cover with canopy stratification (vegetation of tree and food crop) can reduce the rate of erosion caused by rainwater. The economic benefits derived from agroforestry system are that people can still utilize the land by planting seasonal crops on the sidelines of the main crops. The use of such land can be optimized to increase farmers' income (social economy) and to reduce the damage to the environment (ecological aspect). This is in line with the opinion of Shrestha, *et al*.[5], which states that the land use needs to be carried out optimally by considering ecological aspects (erosion, sedimentation, flooding) and socio-economic aspects of society.

IV. Conclusions and recommendations

A. Conclusions

1. Erosion potential (EP)

Characteristics of erosion potential (EP) in the upstream, midstream, and downstream portions of the Amandit catchment were relatively diverse, which included Very Light (0-VL), Light (I-L), Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) and could be developed into the bases for determining the directives of LFR.

In the upstream portion of the catchment, the EP areas of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) of 16,314.95 Ha becoming the targets of LFR activities were larger than the EP areas of Very Mild (0-VL) and Light (I-L), 5352.42 Ha. In the midstream portion of the catchment, the EP areas of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) of 20,334.53 Ha were larger than the EP area of Very Light (0-VL) and Light (I-L), 7,920.89 Ha. On the other hand, in the downstream portion of the catchment, the EP areas of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) were 1,661.41 Ha smaller than the EP areas of Very Light (0-VL) and Light (I-L), 63,858.11 Ha.

2. Directives of Land and Forest Rehabilitation (LFR)

The directives of LFR were determined based on the EP of Moderate (II-M), Severe (III-S) and Very Severe (IV-VS) while the EP of Very Light (0-VL) and Light (I-L) was not included in the directives of LFR, but the areas in these classes were still maintained and preserved.

In the upstream portion of the Amandit catchment, the area included in the directives of LFR was 16,314.95 Ha, consisting of three directives of LFR (Natural Forest Succession, Reforestation Pattern and Agroforestry Pattern with Food Crops).

In the midstream portion of the Amandit catchment, the area for the directives of LFR was 20,334.55 Ha, consisting of seven directives of LFR (Natural Forest Succession, Reforestation Pattern, maintenance of Mixed-species Plantation (MSP) and rejuvenation as well as addition with Multi Purpose Tree Species (MPTS), Afforestation or Industrial Timber Plantation/community forest, Agroforestry pattern with food crops, maintenance of Plantation Forest (PLF) with the pattern

of industrial timber plantation with fast-growing tree species, and maintenance of PLF with the patterns of industrial timber plantation and community forest with fast-growing tree species).

In the downstream portion of Amandit catchment, the area for the directives of LFR was just 1,661.41 Ha, consisting of six directives (Reforestation Pattern, maintenance of Mixed-species Plantation and rejuvenation as well as addition with Multi Purpose Tree Species, Afforestation or Industrial Timber Plantation/ Community Forest, Agroforestry Pattern with Food Crops, maintenance of Settlement (STM) with the development of garden plants, and maintenance of Fields and usage of bench terraces).

B. Suggestions

1. For Mount Kentawan Nature Reserve and Protected Forest, the implementation of Natural Forest Succession and Reforestation Pattern should avoid any disruption that could cause failures since the dominant land covers in the areas are shrubs.
2. Although the Forest Zone and Land Cover with the EP of Very Light (0-VL) and Light (I-L) are not included in the directives of LFR, they should be maintained and preserved, for the preservation of the land.
3. It is recommended to conduct further study with a broader scope, for example, land capability, land suitability and socio-economic aspects (population pressure and support of socio-economic aspects) from the people in the Amandit catchment.

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Appendix 2. Data of Analysis Results of EP Characteristics in Upstream, Midstream, and Downstream Portions of Amandit Catchment

Catchment	FZ	LC	(0-VL)	(I-L)	(II-M)	(III-S)	(IV-VS)	FZ (Ha)	Total FZ (Ha)
Upstream portion	MKNR	SR	0.00	1.62	0.13	3.18	49.51	54.44	54.44
	PF	SR	0.00	450.7	1110.32	3518.77	6374.31	11,454.10	16,587.42
		DA	0.00	0.00	19.98	18.91	96.63	135.52	
		NF	90.75	4657.73	249.32	0.00	0.00	4,997.80	
	PDF	SR	0.00	58.88	465.84	516.69	548.42	1,589.83	1,589.83
	OLU	SR	0.00	89.07	846.49	1467.34	718.94	3,121.84	3,435.68
		DA	0.00	3.67	12.1	2.72	295.35	313.84	
Total			90.75	5,261.67	2,704.18	5,527.61	8,083.16	21,667.37	21,667.37
Midstream portion	MKNR	SR	0.00	1.35	2.56	11.66	168.03	183.60	183.60
	PF	SR	0.00	399.25	198.08	916.10	3381.57	4,895.00	6,782.70
		DA	0.00	86.12	40.04	194.51	925.46	1,246.13	
		MSP	105.94	0.00	0.00	0.00	208.94	314.88	
		PLF	0.00	0.00	0.19	0.00	227.20	227.39	
		OL	0.00	0.00	99.30	0.00	0.00	99.30	
	PDF	OL	0.00	0.00	341.66	118.25	0.00	459.91	10,614.01
		SR	0.00	1289.51	1070.68	844.29	2123.40	5,327.88	
		DA	0.00	447.53	84.04	257.80	404.16	1,193.53	
		MSP	575.08	849.04	416.55	425.62	765.16	3,031.45	

		PLF	68.38	199.00	71.99	91.25	170.62	601.24	
	OLU	SR	0.00	1825.00	870.24	1154.76	2449.31	6,299.31	10,675.22
		DA	0.00	1071.87	334.76	264.10	998.81	2,669.54	
		MSP	764.39	174.90	123.30	0.00	98.87	1,161.46	
		OL	0.00	0.00	259.35	3.24	0.00	262.59	
		PLF	0.00	0.30	8.77	14.93	195.00	219.00	
		F	63.32	0.00	0.00	0.00	0.00	63.32	
Total			1,577.11	6,343.87	3,921.51	4,296.51	12,116.53	28,255.53	28,255.53
Down-stream Portion	KLDB	SR	0,00	10,08	0,00	0,00	0,00	10,08	10.08
	PF	SR	0,00	0,55	0,00	74,48	92,49	167,52	167.52
	PDF	SR	0,00	19,35	0,00	33,76	2,21	55,32	105.67
		DA	0,00	44,46	0,00	0,03	5,86	50,35	
	OLU	SR	0,00	35.005,70	206,56	205,40	486,98	35.904,64	65,236.25
		DA	0,00	968,36	0,00	159,97	220,64	1.348,97	
		MSP	4.525,66	0,06	100,17	1,25	0,00	4.627,14	
		PLF	0,00	0,25	0,00	0,00	0,00	0,25	
		STM	0,00	1.304,62	1,04	0,00	0,00	1.305,66	
		F	21.976,41	2,61	2,51	68,06	0,00	22.049,59	
Total			26.502,07	37.356,04	310,28	542,95	808,18	65.519,52	65,519.52

Notes: FZ = Forest Zone, MKNR = Mount Kentawan Nature Reserve, KLDB = Danau Bangkau protected area, PF = protected forest, PDF = Production Forest, OLU = other land use; EP (0-VL, Very Light), (I-L, Light), (II-M, Moderate), (III-S, Severe), (IV-VS, Very Severe), LC = Land Cover, SR = Shrub, DA = Dryland Agriculture, NF = Natural

Forest, MSP = Mixed-species Plantation, PLF = Plantation Forest, OL = Open Land, STM = Settlement, F = Fields.

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