

Modeling of Erosion on Jelateng Watershed Using USLE Method, Associated with an Illegal Mining Activities (PETI)

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Abstract. The Indonesian archipelago has abundant mineral resources, and it causes many mining activities. Mineral resource is natural based resource which cannot be renewable. An abandon mining pit makes a hole in land surface and it increase the erosion severity level on the rainy season. This erosion would brought sediment to the sea, and it causes damage the ecosystem of the coastal. Erosion modeling in Jelateng watershed performed temporally using remote sensing image data, which consist of LANDSAT-5 (1995), and LANDSAT-8 (2015), and supported by field data as well. The parameters for modeling of erosion through rasterization process as input from erosion USLE models to IDRISI software. The results shown that in 1995, the majority of the area has a low level of erosion. The low erosion rate is less than 183.67 tons/hectare/year and high erosion rate is 408.34 up to 633 tons/hectare/year. Compare with in 2015, erosion models shown that erosion is most prevalent on the upstream area of Jelateng watershed, with low erosion rate is less than 432.2 tons/hectare/year and high erosion rate is 615.64 up to 1448.31 tons/hectare/year.

Keywords: Erosion, Modelling, USLE, Remote Sensing Imagery

1. Introduction

Nature resources exploitation causes excessive damage to nature and it one of the causes of civil conflict. Many mining activities in the Lombok Island found at Sekotong District, West Lombok Regency. From the exploration activities known that the District Sekotong has many mountainous areas which contains minerals, such as gold, copper, and silver. Gold mining found more among other mining activities, since gold mining is the most wanted due to its promising prospect. Over the time, the area that is considered to have the prospect of gold, silver and copper is crowded by gold hunters who most of them are illegal (miners without permission). Illegal gold mining (PETI)'s operation is already extends nearly 1000 hectares into an open, which includes a protected forest area, and also in land owned by citizens. This condition bring in environmental damage to the mining site due to most of illegal miners make holes measuring approximately 1 x 1.5 m² with a depth of up to 3-7 m to get the minerals, and when it is not productive, then it will be abandoned as it is, without any backfilled (Ngurah Ardha, 2010). As a result of this kind of mining operations, mined land cannot function normally back, the land will be exposed due to dredged, and it will be eroded prone in case of heavy rainfall.



2. Method

This study's objective is to analyze LANDSAT OLI and TM imagery for extracting erosion parameters and modeling erosion rate between 1995 and 2015 years in Jelateng watershed. Methodology used in this study can be seen in Figure.1.

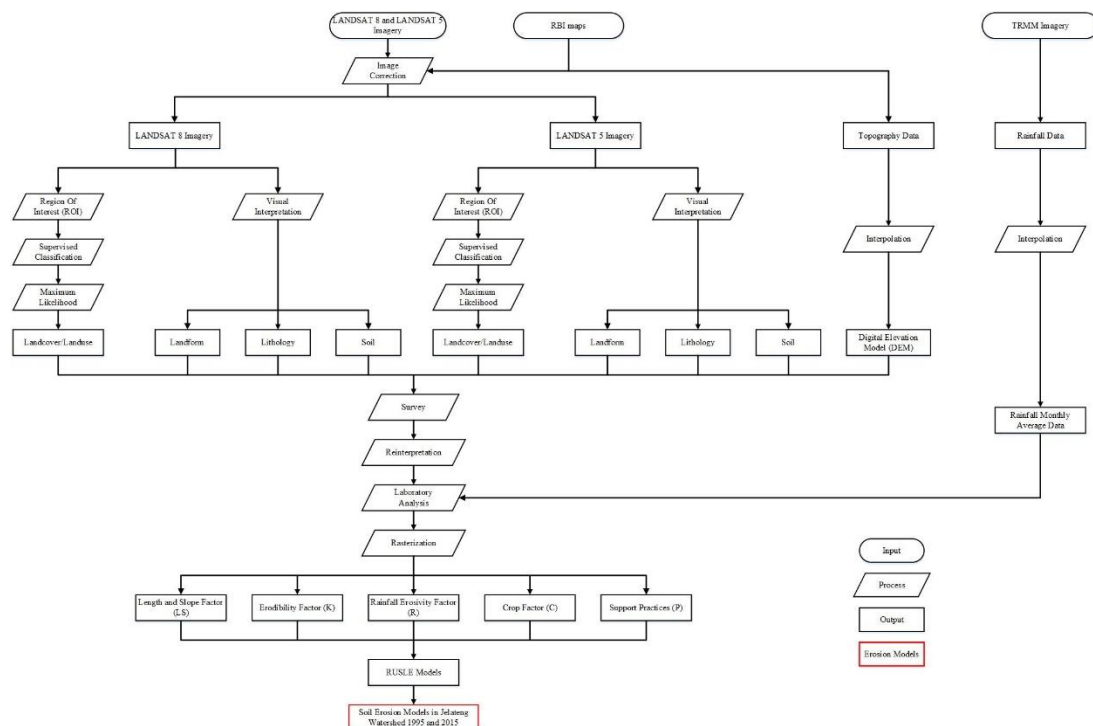


Figure 1. Methodology used in this study

2.1. Erosion Factor

Climate and geology structure are the main factors that influence the process of soil erosion. Besides the characteristics of the soil and vegetation, which both depend on two previous factors and influence each other. Excluding these factors, human activities also gave a significant influence on the change rate of soil erosion (Suripin, 2004). Hardiyatmo (2006), which states that climate change such as hot-cold cycles, wet-dry resulted in the break rocks into smaller particles and weak bond between the particles. In general, the factors that cause soil erosion is consist of:

1. Climate
2. Soil conditions
3. Topography
4. Land cover/land use
5. Soil disturbance due to human activities

2.2. Universal Soil Loss Equation (USLE)

An understanding of the processes of erosion can be obtained more easily by arranging a model. Soil erosion models can be classified into three: a) an empirical model, b) physical models, and c) conceptual model. The empirical model is based on the key variables obtained from research and observation during the process of erosion. One common example of the empirical models used to estimate the magnitude of surface erosion is USLE (Universal Soil Loss Equation), USLE method developed by Wischmeier and Smith (1978) is the most common method used to predict the magnitude of erosion. The term "universal" or "general" this indicates that the equation or the method can be used to predict the

magnitude of erosion for a wide variety of land use conditions and different climatic conditions (Asdak, 1995). Universal Soil Loss Equation is used to determine the weight of soil loss due to erosion. According to Smith and Wischmeier (1978) in Hardiyatmo (2006) the amount of the lost soil is influenced by six factors:

1. The length of the slope
2. The Slope itself
3. Land cover/Land use
4. Soil management
5. Kind of soil
6. Rainfall

USLE allows planners predict an average rate of erosion of certain land on a slope with a particular rainfall pattern for any kinds of soil and the implementation of land management (land conversion). USLE is designed to predict the long-term erosion of sheet erosion (sheet erosion) with erosion groove under certain conditions (Suripin, 2004). To determine the weight of the soil on the surface that lost due to rain, which soil at the surface also contains vegetation. Thus it can be generated using USLE equation (Hardiyatmo, 2006). Based on a statistical analysis of the data of more than 10,000 years of erosion and run off, and management of the physical parameters are grouped into five main variables whose values for each point can be expressed numerically (Suripin, 2004). And based on Forestry Ministry, USLE Formula can be expressed as follows:

$$A = R \times K \times LS \times C \times P$$

Where:

- A = Total soil lost (ton/hectare/year)
- R = Erosivity annual rainfall average (usually expressed as the energy impact of rainfall (MJ/h) x maximum intensity for 30 minutes (mm/h))
- K = soil erodibility index (tonnes x ha x jam) divided by (ha x mega joule x mm)
- LS = Length of slope and slope angle index
- C = Plant management index
- P = Soil conservation effort index

3. Results and Discussion

3.1. Rainfall Erosivity Factor (R)

Rainfall data used from rainfall monthly average data. Rainfall data used has a range of between 5.482 cm to 6.128 cm. Rainfall can be quite low because basically Lombok is a dry area. Although it does not dry as North Lombok which is a shadow-rain area, Jelateng watershed does not have high rainfall variation because only a slight difference of precipitation that falls within Jelateng watershed. Rainfall which comes into the Jelateng watershed can be said spreading evenly. From the calculation rainfall erosivity, showed that the rainfall erosivity index in Jelateng watershed has a value of 22.3537 to 26.0085 cm (Figure.2 and Figure.3), that values are small because erosivity value will directly proportional with rainfall in that area.

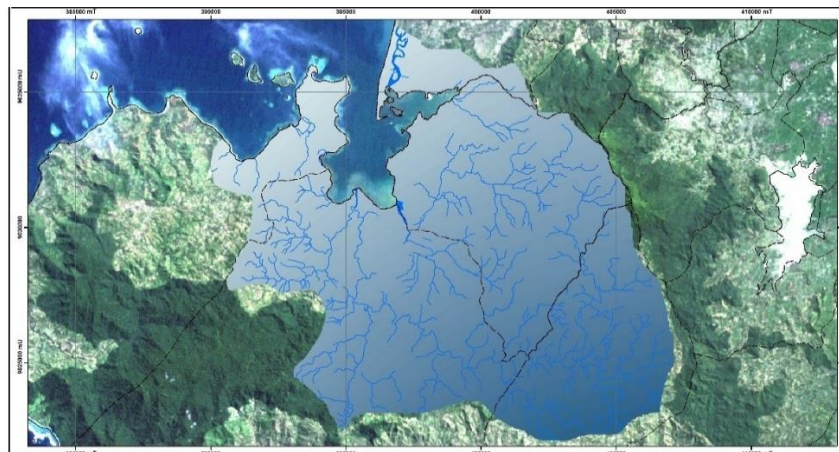


Figure 2. Erosivity factor of Jelateng watershed in 1995

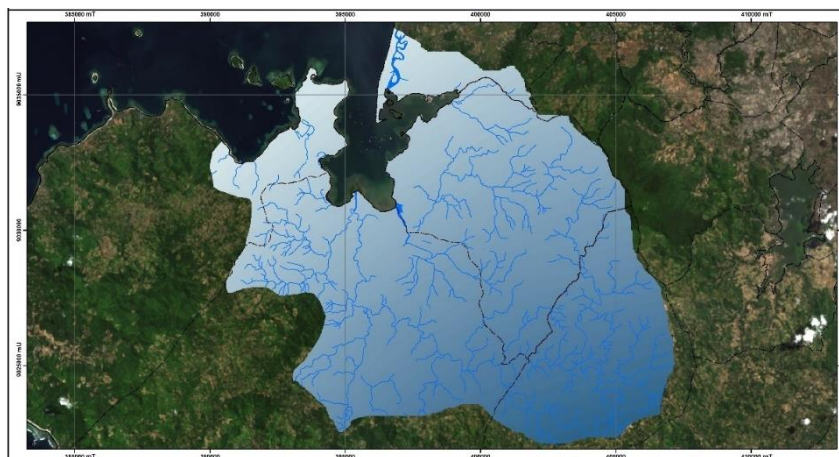


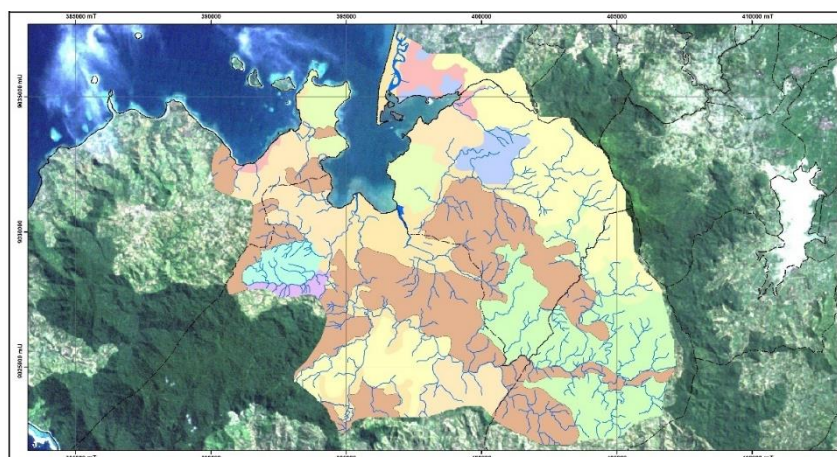
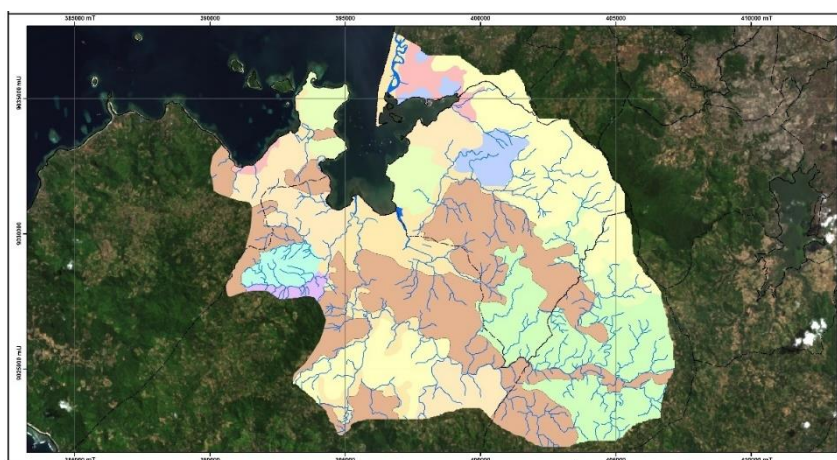
Figure 3. Erosivity factor of Jelateng watershed in 2015

3.2. Erodibility Factor (K)

Erodibility calculations performed highest value obtained on the 6th sample points (Table 1), where the value of erodibility (K) is 0.312. The high erodibility scale is because the soil has low organic material (2.08%). Organic material act as preventing from soil erosion because the organic material acts as a binding agent of soil particles, thus preventing release of particles that cause erosion, besides organic materials also acts to bind water so as to reduce the rate of water can cause erosion. Land at 6th point also has a permeability class incompressible, meaning that the ground is very hard to pass the surface water into the soil so that water will have a strong runoff and cause erosion of the soil surface by the flow of water so that the erosion will be higher. The lowest erodibility occurred in 10th soil sample which has erodibility value is 0.086. Low erodibility value means the land at that point has a high resistance to erosion. Although it has a low organic matter (2.48%) but the ground has a very quick permeability (41.01 cm / h) so that the water infiltrated into the soil so that it will reduce the runoff that will cause erosion. Soil erodibility also influenced by various land use in the area, land use will result in compression of the soil.

Table 1. Erodibility calculations from laboratory analysis

Sample	Organic Material %	Permeabilitas (cm/hour) Value	Class	Lp %	Db %	Ps %	Texture
1.	2.85	1.94	Low	15.09	25.84	59.07	Sandy loam
2.	2.31	2.11	Moderate	35.15	23.33	41.52	Silty loam
3.	2.41	24.74	High	13.79	20.16	66.05	Sandy loam
4.	5.66		-	19.89	23.33	56.77	Sandy loam
5.	3.7	0.63	Low	25.31	27.23	47.47	Sandy loam
6.	2.08		High	12.37	29.6	58.03	Sandy loam
7.	2.8	4.64	Moderate	14.13	19.07	66.8	Sandy loam
8.	1.26	0.14	Low	7.95	22.59	69.47	Sandy loam
9.	6.44	5.41	Moderate	15.12	19.81	65.07	Sandy loam
10.	2.48	41.01	Very High	11.73	22.11	66.16	Sandy loam

**Figure 4.** Erodibility factor of Jelateng watershed in 1995**Figure 5.** Erodibility factor of Jelateng watershed in 2015

3.3. Length and Slope Factor (LS)

Length and slope factor (LS) measurements obtained by the shooting range and slope using Abney level. The field data of 11 samples showed variations in slope, so as to represent the topographical conditions in the Jelateng watershed. Third sample point with slope of 68° and with a short slope length is approximately 8 meters. Lowest degree slope in the sample 2.2 and 3.2 which is 38° with a slope length of approximately 6 meters. Topography-related erosion is not very influential, although the slope on a sample of 2.2, 3 and 3.2 relatively steep to very steep but long slope on the short sample. Unlike the samples of 2.1, 2.2, 2.3, and 2.4 which has a relatively steep slope up to very steep slopes with a length of 15-30 meters. The results of this sample measurement can indirectly illustrate the erosion rate is high as a result of the steep slope and slope length long power lead scraper that water has more power to transport material and runoff will be more. Length and slope factor can provide conditions in the field due to these factors affect the erosion.

Table 2. Slope length and stepness factor

Sample	Slope (Degree)	Slope (Percent)	Slope Length	Factors (L)	Factors (LS)
1	40	83.85	4.25	0.44	13.09
2	54	137.50	6.5	0.54	25.11
2.1	52	127.87	20	0.95	41.88
2.2	38	78.07	6	0.52	14.34
2.2	65	214.13	15	0.82	47.45
2.3	55	142.67	20	0.95	45.11
2.4	60	172.99	30	1.17	61.48
3	68	247.08	8	0.60	36.21
3.1	42	89.97	8	0.60	19.39
3.2	38	78.07	6	0.52	14.34
3.3	50	119.07	5	0.48	19.84

Measurement slope and length data then becomes a factor used to calculate the LS factor. LS factor calculation results show the influence of the length and slope erosion modeling related. The higher value of the length and slope the erosion will be higher it shown with LS factor is also high. Table calculation can be seen in Table 2. LS factor from the results of field measurements indicate the range of values from 13.09 to 61.48.

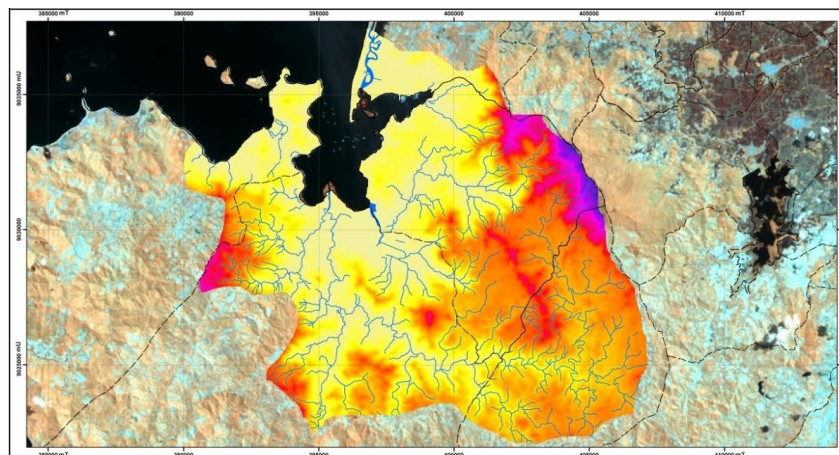


Figure 6. Digital Elevation Model (DEM) of Jelateng watershed

3.4. Crop Factor (*C*)

Factor value of plants used in this study are derived based on land use and direct observations in the field. This is done so that the value obtained is actual or current conditions at the site, so the expected value of the estimate of erosion have a high level of accuracy.

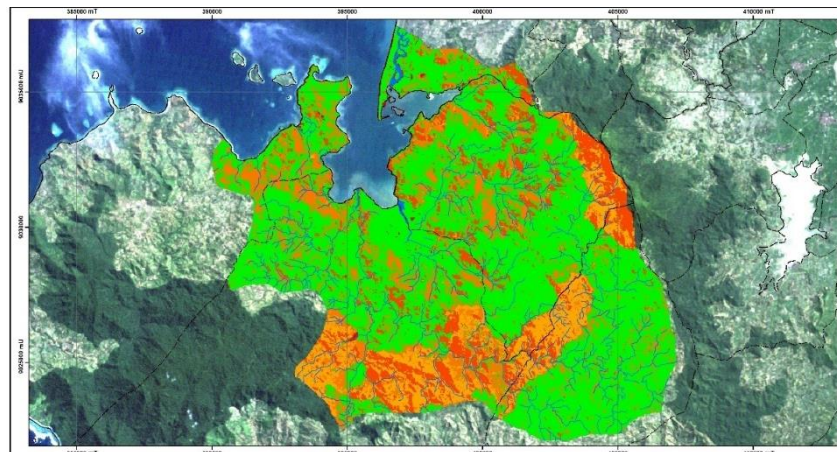


Figure 7. Crop factor of Jelateng watershed in 1995

The parameter value crop factor of 1995 in the Jelateng watershed have a range between 0 to 0.45. When viewed as a whole, the dominant factor is the factor of high density vegetation classes and medium with value 0.01. Parameter value crop factor of 2015 in the Jelateng watershed have a range between 0-0.45. When viewed as a whole, the dominant factor is the factor of medium density vegetation classes (0.01) and low density vegetation classes (0.05). If you look at these two years can be said to occur significant changes in land cover between 1995 and 2015 can be seen with decreasing vegetation density and rising bare land.

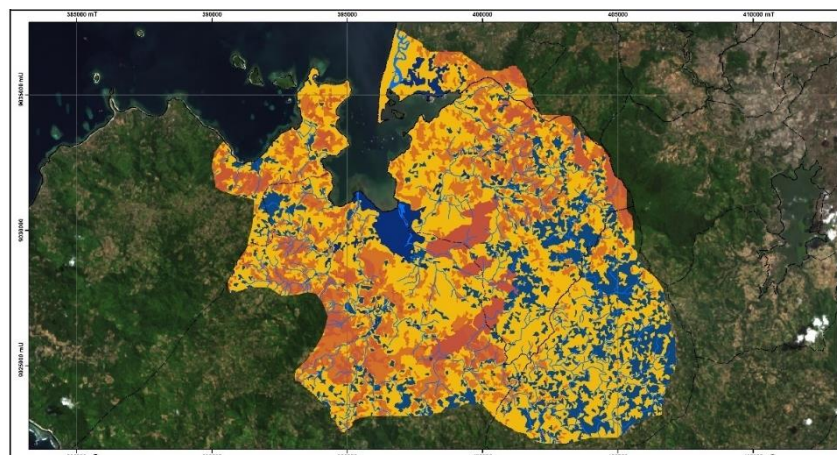


Figure 8. Crop factor of Jelateng watershed in 2015

3.5. Support Practices (*P*)

Conservation factor can be obtained from land cover/land use map. Ground checking must be done before to perform the accuracy of the land cover/land use map and to validate the conservation and soil management factor. Interview method is required to determine the conservation technique that has been used in 1995 and 2015 are the same or equal.

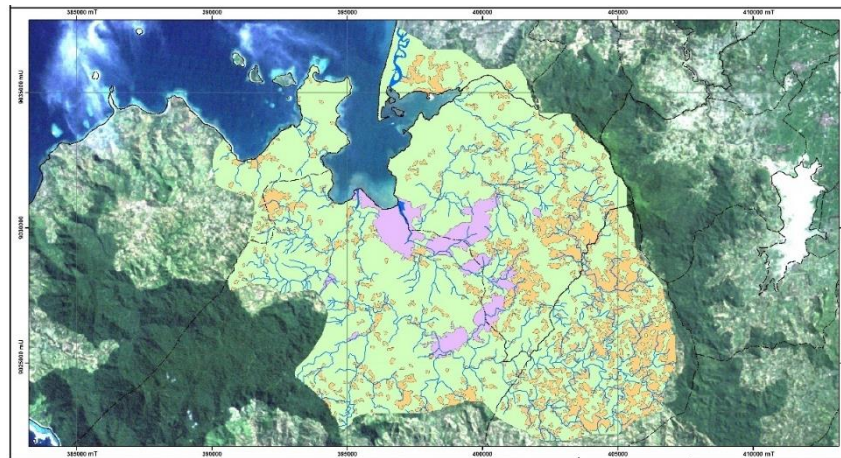


Figure 9. Support practices factor of Jelateng watershed in 1995

Based on this, it can generate three classes value of conservation and soil management factor that been used in 1995 and 2015. The most conservation factors that cause erosion is Condensed and Slippery which has a value of 1.3. Most of this value found at the upstream of Jelateng watershed itself. While conservation which widely used are pedestrian lane towards the top and bottom of the slopes that spread almost throughout Jelateng watershed. This can be seen in Figure 9 and Figure 10.

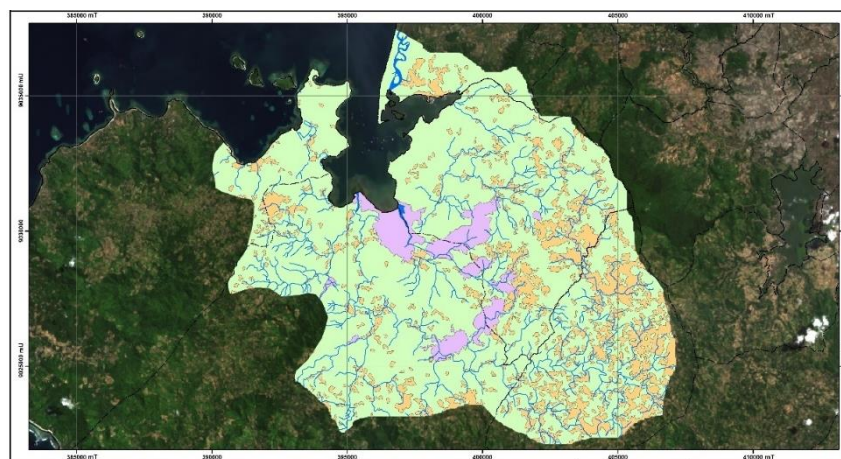


Figure 10. Support practices factor of Jelateng watershed in 2015

3.6. Modelling of Erosion

Erosion modelling carried out after the parameters in the USLE equation predetermined their value, then the erosion rate in Jelateng watershed can be estimated by multiplying the factors of erosion through an empirical equation. There are two modeling is modeling erosion obtained for 1995 and 2015.

The first erosion model is modeling the erosion of 1995. It can be seen in Figure.11 that erosion many occur on the upstream Jelateng watershed. While on the upper and the middle Jelateng watershed are the locations that many established illegal mining (PETI). On the upper and the middle Jelateng watershed can be found their ground grinding process due to the low vegetation cover. The majority Jelateng watershed is a region with a low erosion rate. The low erosion rate less than 183.67 tons/hectare/year and high erosion rate between 408.34 to 633 tons/hectare/year.

The second erosion modelling is modelling the erosion of 2015 (Figure.12) which the erosion much occur on the upstream of Jelateng watershed. Meanwhile on the middle of the Jelateng watershed is the site of the former established illegal mining (PETI). Majority erosion is the erosion with lower classification. The low erosion rate of less than 432.2 tons/hectare/year and highest erosion rate from

615.64 to 1448.31 tons/hectare/year. The erosion rate with a lower classification caused by the activity of the local community to dredge the parent material for use as a building material and their mining activities.

Comparison between modeling erosion in 1995 and 2015 had a significant difference. In 1995 the regions with high erosion class is still quite a lot on the upstream side and middle side which a former illegal miners (PETI) locations. We can see on the figure that dark brown symbol which represent the medium class is still widely spread in many parts of Jelateng watershed. In contrast to modeling erosion 2015. The symbol can be seen predominantly light brown to dark brown. High erosion rate only spread in certain spots. In other words, 2015 is sufficient erosion control.

Differences in erosion between 1995 and 2015 are quite significant. This is because of differences in land cover/land use between these two years. In 1995 where dominated by open land with moderate erosion rates. Land cover/land use of Jelateng watershed in 2015 detected as low density vegetation. This indicated progress in the conservation community from 1995 to 2015. It shows that a large enough public awareness to conserve land cover/land use where formerly open land, then began to be used to reduce the rate of soil erosion.

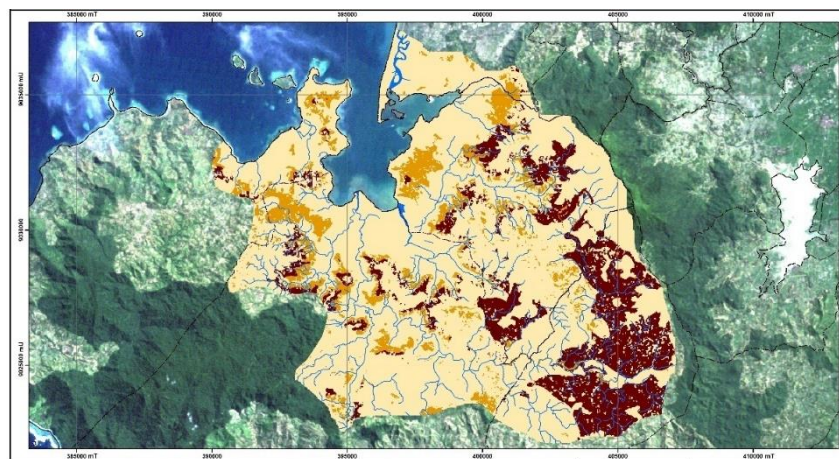


Figure 11. Soil erosion models in Jelateng watershed 1995

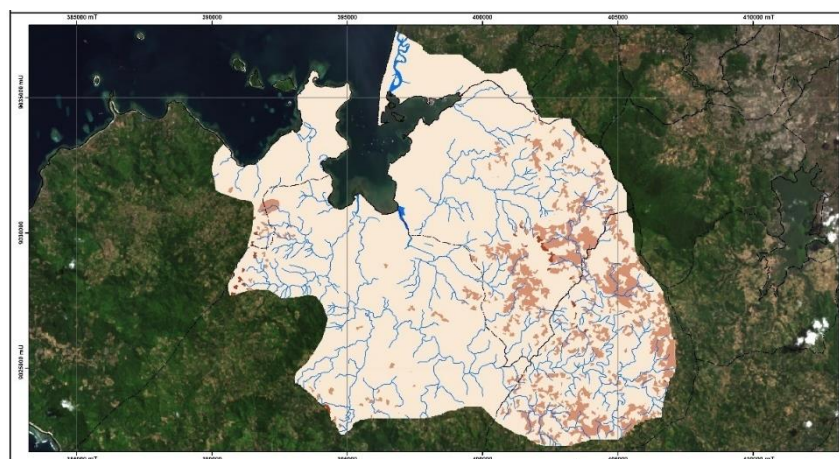


Figure 12. Soil erosion models in Jelateng watershed 2015

4. Conclusion

Based on research that has been conducted and the results have been obtained, (1) LANDSAT-8 and LANDSAT-5 imagery were able to provide information related to modeling parameters erosion. The parameters can be extracted ie landforms, rocks, soil, and land cover/land use where the parameter is used to create land units maps. In modeling erosion in 1995 and 2015, information which has obtained from remote sensing imagery combined with field data and collaborated with laboratory analysis. (2) Results of this study shown that USLE model in IDRISI software were able to modeling soil erosion intensity at Jelateng watershed.

References

- [1] Ardha N 2010 Memburu Emas di Sekotong Lombok Barat
<http://www.esdm.go.id/berita/artikel/56-artikel/4012--memburu-emas-di-sekotong-lombok-barat.html>.
- [2] Arsyad S 2000 Konservasi Tanah dan Air (Bogor : IPB Press)
- [3] Asdak C 1995 Hidrologi dan Pengelolaan Daerah Aliran Sungai (Yogyakarta : Gadjah Mada University Press)
- [4] Departemen Kehutanan 1998 Pedoman Penyusunan Rencana Teknik Rehabilitasi Teknik Lapangan dan Konservasi Tanah Daerah Aliran Sungai (Jakarta : Departemen Kehutanan)
- [5] Hardiyatmo 2006 Penanganan Tanah Longsor dan Erosi (Yogyakarta : Gadjah Mada University Press)
- [6] Suripin 2004 Pengembangan Sistem Drainase Yang Berkelanjutan (Yogyakarta : Andi Offset)