International Journal of GEOMATE, Nov., 2019 Vol.17, Issue 63, pp. 371- 377
ISSN: 2186-2982 (P), 2186-2990 (O), Japan, DOI: https://doi.org/10.21660/2019.63.48290
Geotechnique, Construction Materials and Environment

ANALYSIS OF EROSION USING HYDROSEEDING ON POST COAL MINING IN MELAK SITE

* Waterman Sulistyana Bargawa, Arisdiansyah Putra, M. Nurcholis

Faculty of Mineral Technology, UPN Veteran Yogyakarta, Indonesia

*Corresponding Author, Received 09 April 2019, Revised 22 May 2019 Accepted: 10 June 2019

ABSTRACT: After the mining process, Melak coal mining conducts reclamation. One of the problems is the steep slope caused by the coal exploitation process. The slope is difficult to be replanted and the soil is easily eroded by rainwater. The hydroseeding combined with jute net method has been applied in this area, but the effectiveness and success of using that method have not been measured accurately. Therefore, this study aims to examine explicitly the effectiveness of hydroseeding combined with jute net method on the amount of erosion in this Melak Coal Mining site especially at the disposal slopes and low wall in pit. The observation was done by making two square area models in separate locations, which applied jute net and without jute net combined with hydroseeding technique. The seeds used were Centrosema Pubescens, Pueraria Javanica, and Calopogonium Mucunoides. Next, the actual erosion was compared to erosion prediction using the USLE. The average results of the actual erosion were: at jute net disposal 471.59 ton/acre and at non-jute net disposal 510.19 ton/acre; and at jute net in pit 896.23 ton/acre and at non-jute net in pit 974.43 ton/acre. The results of USLE calculation method were: at jute net disposal 944.56 ton/acre and at non-jute net disposal 1016.81 ton/acre; and at jute net in pit 1805.31 ton/acre and at non-jute net in pit 1917.10 ton/acre. The results indicated that the method was able to reduce about 89.57% of the sediment accumulation at disposal and about 96.62% at low wall.

Keywords: Erosion, Revegetation, Hydroseeding, Jute net, USLE

1. INTRODUCTION

An after-mining process will cause a steep slope surface which has tendency for erosion or the worst case is landslide. Appropriate revegetation technique and type of plants are required to complete the reclamation process at the steep slope. It is known that hydroseeding brings out the best result, but it is also known as a less economical technique [1]. Since it is important to know the most appropriate and economical method, this research was conducted to test the use of hydroseeding technique combined with jute net materials [2].

The primary factor in the success of the reclamation process is soil fertility. Type of cover crop used was Leguminosae. It is believed that Leguminosae capable of increasing soil fertility along with its chemical properties. Leguminosae can build a symbiotic relationship with Rhizobium bacteria and fixate nitrogen in the water. Furthermore, when it is combined with manure, Leguminosae is capable of accumulating nitrogen in the soil and turning it into natural soil fertilizer [3].

The experiment was conducted at the ex-mining area of Melak Coal Mining site which is located in Kutai Barat, East Kalimantan Province. This research was conducted using hydroseeding combined with jute net materials from coconut fiber or coir established at the disposal location and low wall in pit of ex-mining land. The observation area was 2 x 2 m^2 adjusting to the steep terrain of the after mining land. From the runoffs, both rainwater, and sediment, to be analyzed, were accommodated in the buckets below each plot designs. The growth of the cover crop coverage was also analyzed to examine the effect of the technique in attempt to resolve the soil erosion problem. It was hoped that the erosion and sedimentation process from the runoff on the after mining steep slope can be reduced [4].

The unique method used in this study was the observation done in natural/actual conditions (soil condition, weather, and rainfall). The investigation period was within 3 months when the peak of rainfall happens for a year. The method in this study has not been provided by other researchers. Most of experiment used simulation method [4], [14], [15]. It differentiates this research from the previous research.

The hydroseeding combined with jute net method has been applied in this area, but the effectiveness and success of using that method have not been measured accurately. Therefore, this study aims to examine explicitly the effectiveness of hydroseeding combined with jute net method on the amount of erosion in this Melak Coal Mining site. This study is able to provide results quantitatively to calculate the effectiveness.

2. RESEARCH METHOD

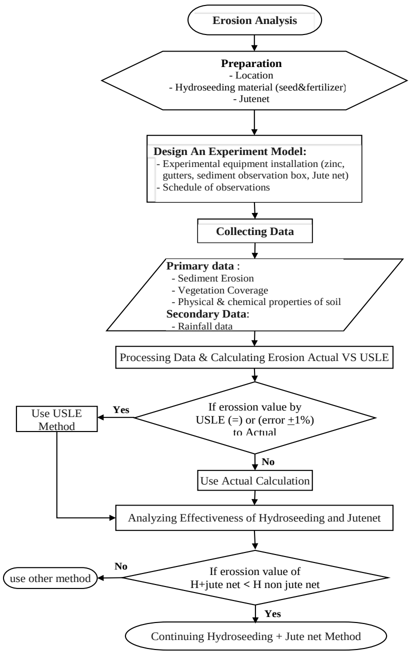

Fig. 1 Flow chart of research methodology

This research was taken place at concession area of PT. TCM, PIT. 3000 B03. Administratively, this research location is included in the Muara Lawa, Bentian Besar, and Damai sub-district, West Kutai district, East Kalimantan.

Geographically, it is located at E 115°38’40.41” and S 0°41’50.06”. Location selection was done purposively with the following considerations:

1. The research location has an important function as a revegetation area, slope buffer, and water infiltration so that no landslides occur at the ex-mining land during the rainy season.
2. Ecological condition at the location has undergone degradation up to a critical point due to the erosion during rainy seasons. Figure 1 shows the condition of the steep slope at the research location after landslide occurs.

Fig. 2 Steep slope condition at the location

2.1 Actual Erosion by Small Plot Method

Observation and measurement method were done to analyze the effectivity of hydroseeding combined with jute net materials. Erosion and runoff measurement were done by establishing erosion distribution design plots as follows :

a) Erosion plot was established using a square plot with a size of 2 x 2 m^2 (adjusting to the location condition). Erosion plot was established in 2 conditions, with jute net and non-jute net.
b) Each square was divided into 3 columns with a size of 2 x 0.6 m^2 in order to get repetition data.
c) At the base of the slope, a gutter and a container bucket were established for each plot. These buckets served to collect eroded soil and runoff.
d) Eroded soil and runoff collected in the bucket were graded to obtain and then observe the volume and erosion-induced sediments.
e) Graded sediments from the bucket were put in an oven, then we measured the dry weight of the eroded soil per unit area per day of rain.

Sediments and rainwater samples were taken every rainy day using a 200 ml sample bottle. Erosion samples were then dried in an oven and then weighed to measure the amount of erosion per erosion plot design.

Next, the data were gathered into the sample plastics and labeled based on the date and code zone. After that, the actual measurement of the samples was done.

2.2 Erosion Prediction by USLE Method

The estimated amount of soil erosion was conducted using the following Universal Soil Loss Equation (USLE) formulation [5]:

$$A = R \times K \times LS \times C \times P \quad (1)$$

The results of the analysis using the USLE formula were used as a comparison from the results of each data per day of rainy day event at the location observed.

2.2.1 Rainfall Erosivity Factor (R)

Erosivity is defined as the kinetic energy of rainfall to cause soil erosion. The greater the erosivity, the greater the amount of eroded soil (directly proportional). Rainfall erosivity index was calculated for each plot as stated above. Rainfall data used in this research were the average from 2015 until 2018. The rainfall erosivity was calculated using the formulation below [6]:

$$R = 0.548257 \times P - 59.9 \quad (2)$$

where P = yearly rainfall (mm)

2.2.2 Soil Erodibility Factor (K)

Soil erodibility is related to the soil physical properties, including texture, organic matter percentage, and permeability. Generally, soil with low erodibility has low proportion for silt and dust, a high proportion of organic matter content, fine structure, and high permeability. The soil erodibility was calculated using formulation as follows [7]:

$$K = \frac{2.173x(2.1xM^{1,14}x(10^{-4})x(12-a)+3.25x(b-2)+2.5x(C-3))}{100} \quad (3)$$

where K = Soil erodibility factor (ton.ha.thn), M = (% dust+ % silt) x (100 - % clay), a = organic atter percentage (% C x1.724), b = soil structure classification, C = soil permeability classification

2.2.3 Topographic Factor (LS)

LS is the ratio between the amount of erosion at a plot of land with a slope length and a certain steepness, toward the erosion rate on a slope which has a length (λ) and steepness (°). The value of LS is calculated from the below equation [8]:

$$LS = (\frac{\lambda}{22.13})^{m} \cdot (65.41 \cdot Sin^{2}\theta + 4.56 \cdot Sin\theta + 0.065) \quad (4)$$

where λ = slope length, m = contants depends on the slope steepness (m = 0.2 for <1%, m = 0.3 for = 1– 3%, m = 0.4 for = 3.5–4.5%, and m = 0.5 for > 5%), θ = steepness angle.

2.2.4 Cropping Management Factor (C), Conservation Management Factor (P)

Cropping/plant coefficient (C) and land management (P) factors refer to the results of the characteristics of land units at the research location.

2.3 Quality of Soil Properties

Soil sampling was done to determine the chemical and physical properties of the soil by stratified purpose sampling based on its land units.

Soil samples were collected from 2 location with 2 different conditions for each location. Soil samples were taken at a depth of 5 cm using ring samples, as much as 16 samples [9].

Soil samples from the research location were analyzed at the laboratory to obtain the exact chemical and physical properties indexes. There were two samples taken, before and after the cover crops were planted. It was done to examine the soil properties changes at the research location.

2.4 Coverage of Cover Crop

The parameter measured was the percentage of the cover crops coverage. Measuring the area of closure against the cliff was done by comparing the area reached from plant propagation, then divided by the area of the jute net. The coverage percentage was calculated according to the formulation as follows [10]:

$$PAC = \frac{\Delta A}{TA} \times 100 \quad (5)$$

where PAC = percentage area change, TA = total area, ΔA = change area.

A tool to measure the coverage of cover crop from each zone observed was a wooden frame in size of 0.6 m X 0.6 m divided by threads with a size of 0.1 m for each square. In order to collect the statistic value for data observation, each column was divided into 3 observation zones (zone A, B, C). The observation was done once a week and then recorded in the observation table.

The measurement of cover crops coverage was done every week starting from the first week, the planting process, until the last week of observation to see the effectiveness of the cover crops reducing the possibility of erosion.

2.5 Level of Potential Erosion

Average annual erosion was considered to determine the level of potential erosion that occurs for each unit of land plot at the observation location [11]:

Table 1. Level of average annual soil loss from erosion

Soil loss rate (ton/ha/th)	Erosion level
<10	Low
10-50	Moderate
50-200	High
>200	Very High

3. RESULTS AND DISCUSSION

3.1 Measurements of Sedimentation Erosion

Tables 2 and 3 show the results of sedimentation gained with and without jute net in low wall in pit and disposal area. The measurement results of sedimentation erosion and runoff at disposal location were based on every rainfall event from December 2017 until March 2018. The data of soil erosion occurred are gained from the measurement of collected sample bottles that had been coded according to the location and date of data collection.

From the results in Table 2, in jute net disposal location, the highest average sediment was 166.44 gr/m^2 and the lowest average was known as much as 2.02 gr/m^2. Highest average sedimentation at non-jute net disposal location was 417.66 gr/m^2 and the lowest average was 2.81 gr/m^2. Data in Table 2 is described in Figure 4.a and Figure 4.b.

From the results in Table 3, in jute net in pit location, it was known that the highest average sediment was 65.88 gr/m^2 and the lowest average was 1.23 gr/m^2. Highest average sediment at the non-jute net in pit location was 823.73 gr/m^2 and the lowest average was 0.71 gr/m^2. Data in Table 2 are described in Figure 4.c and Figure 4.d.

In the early period of observation, the hydroseeding combined with jute net method resulted in less sediment erosion gained than without jute net. As the rainfall increased, the sediment erosion increased. The peak of the sediment amount occurred in the peak rainfall happened. On January 11th, 2018, the sediment decreased as rainfall decreased. After January 14th, 2018, the sediment decreased even though the rainfall increased. This trend occurred in low wall in pit and disposal area, with or without jute net. The phenomenon of decreased sediment even though the rainfall increase is related to the cover crop coverage and will be explained in subsection 3.2.

Table 2. Observation of sediment erosion at disposal location

Date	Rainfall (mm)	Jute Net Disposal Sediment (gr)				Non-Jute Net Disposal Sediment (gr)			
		Column 1	Column 2	Column 3	Mean	Column 1	Column 2	Column 3	Mean
17-12-25	13.00	28.69	68.65	154.3	83.88	97.99	79.52	44.51	74.01
17-12-26	76.00	40.07	79.46	291.8	137.11	413.44	292.56	25.14	243.71
17-12-28	81.00	71.79	204.01	223.53	166.44	712	308.35	232.63	417.66
18-01-11	27.00	23.74	6.66	7.1	12.50	11.48	12.04	34.86	19.46
18-01-14	3.00	2.04	1.87	2.14	2.02	1.48	5.07	4.6	3.72
18-01-18	9.00	7.47	6.77	6.33	6.86	18.05	23.83	14.12	18.67
18-03-20	15.50	1.99	3.54	2.46	2.66	3.48	3.15	1.8	2.81

Table 3. Observation of sediment erosion at the low wall in pit location

Date	Rainfall (mm)	Jute Net In pit Sediment (gr)				Non-Jute Net In pit Sediment (gr)			
		Column 1	Column 2	Column 3	Mean	Column 1	Column 2	Column 3	Mean
17-12-25	13.00	18.69	8.19	1.61	9.50	52.19	71.29	39.73	54.40
17-12-26	76.00	76.67	64.54	56.43	65.88	822.5	823.6	825.1	823.73
17-12-28	81.00	24.9	13.48	20.18	19.52	335.94	978.93	826.96	713.94
18-01-11	27.00	2.43	2.52	9.95	4.97	3.47	3.21	5.64	4.11
18-01-14	3.00	1.17	2.91	1.06	1.71	1.3	1.09	2	1.46
18-01-18	9.00	3.28	2.72	4.09	3.36	3.57	3.04	4.53	3.71
18-03-20	15.50	1.9	0.82	0.96	1.23	1.13	0.11	0.9	0.71

Natural factors which affected the erosion process might be specified from the effects contributed to the erosion and sedimentation process. Several factors that influenced the magnitude of erosion were rainfall, soil properties, slope steepness, vegetation, and land use [5].

The high intensity of rainfall will increase the rate of erosion that occurs at the surface of the soil. Soil lump that disintegrated due to the kinetic energy of rainfall will transport the soil grains from the surface of the land [12]

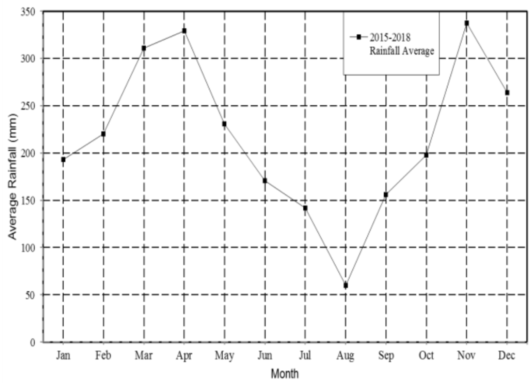

Fig. 3 Average rainfall curve at PIT 3000 B.03 as the observation location

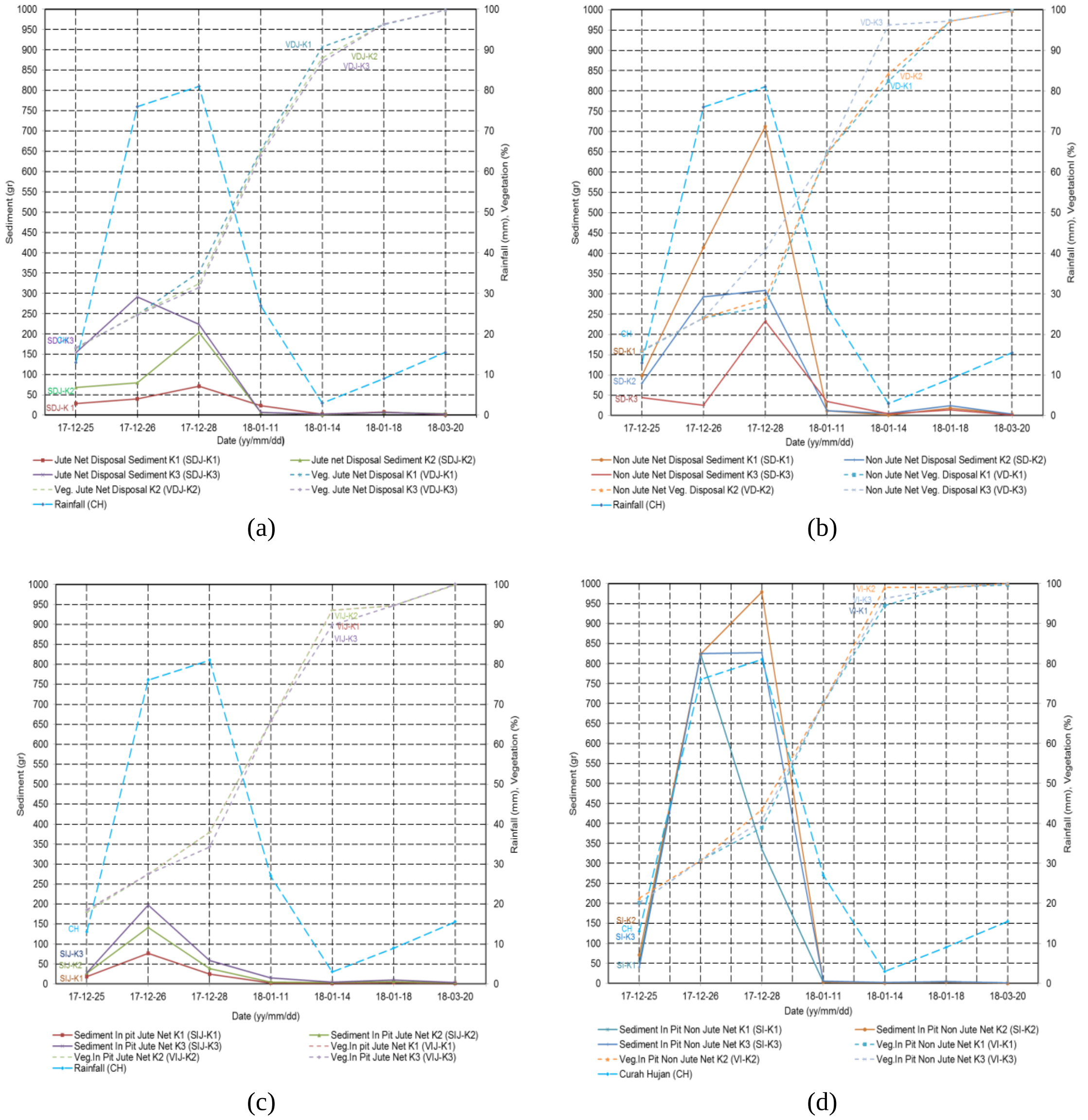

Fig. 4 (a) Erosion curve at jute net disposal location, (b) Erosion curve non-jute net disposal location, (c) Erosion curve at jute net low wall in pit, (d) Erosion curve at the non-jute net low wall in pit

3.2 Vegetation Coverage

Ground cover crops in this research served as slope covering in order to reduce soil surface damage by rainwater. The hydroseeding method was done by mixing all the seeds sprayed evenly across the slopes of the research location. The cover crops needed three months to cover the soil surface evenly. This reclamation process using cover crops was expected to cover the surface of the after mining steep slope in the fastest possible way so that the erosion possibility by rainfall runoff could be reduced.

The effectiveness of cover crops in controlling erosion was affected by the characteristics of cover crop types. The amount of sediment from erosion decreases exponentially with vaster crop cover coverage. The more slopes covered by cover crops, the better the protection given toward soil erosion. Apart from being able to control erosion due to rainfall, crop cover can also control erosion caused by wind by intercepting the wind.

Vegetation coverage had indirectly detained the erosion process at the observation location. Moreover, the measurements of cover crops growth at low wall in pit location, with or without jute net, after 3 months achieved 100% accretion.

Vegetation factor plays a very important role in erosion, vegetation can prevent rainwater from falling directly to the ground. Effective vegetation to control erosion is a well-managed forest. Apart from forests, vegetation that is effective in controlling erosion is grass. Thus, the management of forests and grasslands is very important in maintaining soil stability [13].

The average of actual erosion condition at jute net disposal location was approximately 471.59 ton/acre and at non-jute net disposal location was approximately 510.19 ton/acre. Furthermore, at the jute net in pit location, the average of actual erosion gained was approximately 896.23 ton/acre and at the non-jute net in pit location was approximately 974.43 ton/acre.

Meanwhile, using the USLE calculation method, the amount of soil erosion at jute net disposal location was approximately 809.06 ton/acre and at non-jute disposal location was approximately 870.95 ton/acre. At jute net in pit location, the soil erosion was approximately 1546.34 ton/acre, and at the non-jute net in pit location was approximately 1642.09 ton/acre.

From the research results, it was found that the erosion from using USLE calculation method was greater than the actual erosion. The results of USLE calculations are greatly affected by annual rainfall data along with the soil physical properties index. The results of both methods are included in very high-level erosion according to the classification of the level of erosion

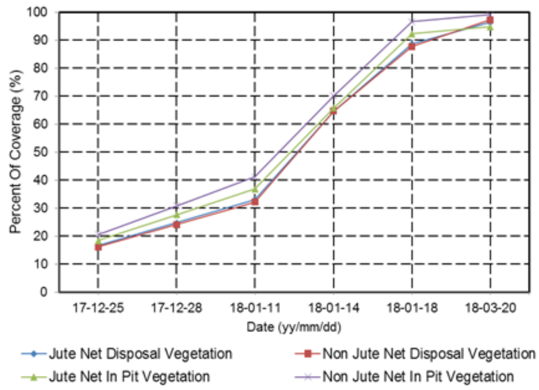

Fig. 5 Vegetation coverage percentage

Table 4. Comparison value of the annual erosion between actual and USLE method calculations

Code	Actual Erosion	Erosion using USLE method
	ton/ha/thn	ton/ha/thn
JN disposal k1	516.47	768.31
JN disposal k2	564.81	838.22
JN disposal k3	555.4	820.65
N-JN disposal k1	597.95	877.72
N-JN disposal k2	586.87	867.16
N-JN disposal k3	584.65	867.96
JN In pit k1	1053.72	1570.1
JN In pit k2	1035.51	1543.31
JN In pit k3	1023.63	1525.6
N-JN In pit k1	1147.22	1697.24
N-JN In pit k2	1136.33	1635.04
N-JN In pit k3	1090.17	1593.98

3.3 Comparison between USLE Calculation and Actual Measurement

In the USLE method, the rainfall data used the erosivity calculation, and the soil properties used the erodibility calculations. Those parameters greatly influence the results of the erosion calculations in the USLE method.

The observation results showed that the combination of the hydroseeding method with jute net at disposal was able to reduce the cumulative sediment by 89.57% and the low wall in pit by 96.62%.

Actual erosion gained at jute net disposal location was 471.59 ton/acre, at non-jute net disposal location was 510.19 ton/acre. Actual erosion gained at jute net in pit location was 896.23 ton/acre, and at the non-jute net in pit location was 974.43 ton/acre. Through USLE method calculations, the erosion gained at jute net disposal location was 944.56 ton/acre, at non-jute net disposal location was 1016.81 ton/acre. At jute net in pit location, the erosion was 1805.31 ton/acre, and at the non-jute net in pit location was 1917.10 ton/acre.

The results of erosion calculations using the USLE method were 47.8% greater than the actual calculation of erosion. This difference can be used as a rule of thumb in actual calculations in the field because this difference is the same in each calculation (Table 4).

4. CONCLUSION

1. The results of the USLE method were about 47.8% higher than the actual measurement. Therefore it could not be used as an approach method for this case.
2. The observation result shows that combination of hydroseeding with jute net method is capable to reduce sediment cumulative as much as 89.57% at the disposal location and as much as 96.62% at low wall in pit. It means this method is proven to be effective in reducing erosion for PT. TCM post-mining area. This method is recommended to be continued.
3. The growth of the cover crops in every week greatly affected the reduction of sedimentation erosion possibility at the research location. The technique application with or without jute net is not significant, as shown by the percentage of success after three months growth, which was 99.7%. Furthermore, there is a possibility to conduct this research at a similar location.

5. ACKNOWLEDGMENTS

We thank the Academic Supervisor of the Mineral Technology Faculty, UPN Veteran Yogyakarta, Indonesia, for the vast knowledge given to the completion of this research.

Thank you for my beloved wife who has provided us with moral support and prayers.

6. REFERENCES

[1] Azalia D., Retnaningdyah C., Endang Arisoesilaningsih (2016) Germination of seeds of some local pioneer plant species in different hydroseeding mulches for revegetation of post-coal mining soil. Journal Of Degraded And Mining Lands Management ISSN: 2339-076X (p); 2502-2458 (e), Vol.3, No.4, pp. 609-615. doi : 10.15243/jdmlm.2016.034.609

[2] Sanyal T. (2017) Control of Soil Erosion Caused by Rain and Wind with Jute Geotextiles., Jute Geotextiles and their Applications in Civil Engineering. Developments in Geotechnical Engineering. Springer, Singapore, pp 41-63

[3] Antoine Le Quéré, Nisha Tak, Hukam Singh Gehlot, Celine Lavire, Thibault Meyer, David Chapulliot, Sonam Rathi, Ilham Sakrouhi, Guadalupe Rocha, Marine Rohmer, Dany Severac, Abdelkarim Filali-Maltouf and Jose-Antonio Munive (2017) Genomic characterization of Ensifer aridi, a proposed new species of nitrogen-fixing rhizobium recovered from Asian, African and American deserts., Doi: 10.1186/s12864-016-3447-y

[4] Kalibová, J., Petrů, J. & Jačka, L. Environ Earth Sci (2017) pp. 76-429.doi.org/10.1007/s12665-017-6746-y

[5] Aafaf El Jazouli, Ahmed Barakat, Abdessamad Ghafiri, Saida El Moutaki, Abderrahim Ettaqy, Rida Khellouk, (2017) Soil erosion modeled with USLE, GIS, and remote sensing: a case study of Ikkour watershed in Middle Atlas (Morocco) Geosci. Lett., doi 10.1186/s40562-017-0091-6

[6] Tung gia pham, Jan Degener, Martin kappas (2018) Integrated universal soil loss equation (USLE) and Geographical Information System (GIS) for soil erosion estimation in A Sap Basin: Central Vietnam. ISWCR, Vol.6 : 99-110., Doi. org/ 10.1016/ j.iswcr. 2018. 01. 001

[7] Asma Belasri, Abdellah Lakhouili (2016) Estimation of Soil Erosion Risk Using the Universal Soil Loss Equation (USLE) and Geo-Information Technology in Oued El Makhazine Watershed, Morocco. Journal of Geographic Information System, Vol.08, 98-107., Doi : 10.4236/ jgis. 2016. 81010

[8] S.Dutta (2016) Soil erosion, sediment yield and sedimentation of reservoir. Model. Earth Syst. Environ 2:123., DOI 10.1007/s40808-016-0182-y

[9] Irene García-Gonzáleza, Chiquinquirá Hontoria, José Luis Gabriel, María Alonso-Ayuso, Miguel Quemada (2018) Cover crops to mitigate soil degradation and enhance soil functionality in irrigated land, Geoderma 322:81-88, https://doi.org/10.1016/j.geoderma. 2018. 02. 024

[10] Muhammad Sabiu Suleiman, Oliver Vivian Wasonga, Judith Syombua Mbau and Yazan Ahmed Elhadi (2017) Spatial and temporal analysis of forest cover change in Falgore Game Reserve in Kano, Nigeria. Ecological Processes 6:11., DOI 10.1186/s13717-017-0078-4

[11] David Hernando, Manuel G. Romana, (2015) Development of a Soil Erosion Classification System for Cut and Fill Slopes. Transp. Infrastruct. Geotech 2: 155-166., DOI 10.1007/s40515-015-0024-9

[12] Lei lei Wen, Fenli Zheng, Haiou Shen, Feng Bian, Yiliang Jiang (2015) Rainfall intensity and inflow rate effects on hillslope soil erosion in the Mollisol region of Northeast China. Nat Hazards 79 : 381-385., doi. org/ 10.1007/ s11069-015-1847-y

[13] Vibhash Ranjan, Phalguni Sen, Dheeraj Kumar, Arjun Sarsawat (2015) A review on dump slope stabilization by revegetation with reference to indigenous plant. Ecological Processes 4:14., doi 10.1186/s13717-015-0041-1

[14] Mervin M. Cereno, Fibor J. Tan and Francis Aldrine A. Uy (2015) Combined *Hydroseeding* and Coconet Reinforcement for Soil Erosion Control., Mapua Institute of Technology Philippines., 11 Maret 2015

[15] Moreno-Ramon, H., Quizembe, S. J., and Ibanez-Asensio, S. (2014) Coffee husk mulch on soil erosion and runoff, experiences under rainfall simulation experiment, Solid Earth, 5, 851–862, doi:10.5194/se-5-851-2014.

Copyright © Int. J. of GEOMATE. All rights reserved, including the making of copies unless permission is obtained from the copyright proprietors.