Vol. 12, No. 1 (2023) : 223 - 235 DOI : http://dx.doi.org/10.23960/jtep-l.v12i1.223-235

JURNAL TEKNIK PERTANIAN LAMPUNG

ISSN 2302-559X (print) / 2549-0818 (online)
Journal homepage : https://jurnal.fp.unila.ac.id/index.php/JTP

Estimation of Erosion Potentials through Utilization of Remote Sensing Data and The Universal Soil Loss Equation Model

Arif Faisol [1]✉, Mashudi[2]

[1]Department of Agricultural Engineering and Biosystem, Faculty of Agricultural Technology, Universitas Papua, Papua Barat, INDONESIA
[2]Department of Soil Sciences, Faculty of Agriculture, Universitas Papua, Papua Barat, INDONESIA

Article History :

Received : 30 August 2022
Received in revised form : 12 January 2023
Accepted : 18 January 2023

Keywords :
Erosion rate,
Remote sensing,
Tolerable soil loss,
USLE,
Watershed.

✉Corresponding Author:
arif.unipa@gmail.com

ABSTRACT

Remote sensing data and USLE models have been used widely for erosion analysis. In Indonesia, the USLE model is a reference in erosion analysis to assess land suitability for agricultural crop development. Erosion analysis using remote sensing data provides various advantages, including good accuracy, lower costs, and can analyze erosion rates quickly compared to direct measurement methods. The aim of this study was to analyze the potential erosion in the Arui watershed - Manokwari Regency – West Papua Province using remote sensing data and USLE models. The research was conducted from April to July 2022, with three main stages i.e data inventory, data analysis, and erosion rate estimation. The research shows that the potential erosion rate in the Arui watershed is 15 tons/ha/year or 3.480 tons/year, thus exceeding the tolerable soil loss (TSL) erosion rate threshold of 9.6 tons/ha/year. Therefore, a conservation and restoration program is needed to control the erosion rate in the Arui watershed.

1. INTRODUCTION

Soil erosion assessment is an important step to determine the magnitude of the rate of soil erosion and the level of its danger. The USLE (Universal Soil Loss Equation) is one of the erosion analysis models established in 1965 by Wischmeier and Smith (USDA, 1978). USLE is still widely used in the world although currently more than 80 erosion analysis models have been developed (Karydas *et al.*, 2014; Raza *et al.*, 2021). Some of the well-known models include the Revised-USLE and Modified-USLE, CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), ANSWER (Area Nonpoint Source Watershed Environment Response Simulation), EPIC (Erosion Productivity Impact Calculator), GAMES (Guelph Model for Evaluating the Effects of Agricultural Management Systems on Soil Erosion and Sedimentation), MADALUS (Mediterranean Desertification and Land Use), WEPP (Water Erosion Prediction Project), LISEM (Limburg Soil Erosion Mode), EUROSEM (European Soil Erosion Model), DWEPP (Dynamic Water Erosion

Prediction Project), APEX (Agricultural Policy Environmental Extender), MMF (Morgan, Morgan, and Finney), WESP (Watershed Erosion Simulation Program), AGNPS (Agricultural Non-point Source model), KINEROS (Kinematic run-off and Erosion model), USPED (Unit Stream Power-based Erosion Deposition), HEM (Hillslope Erosion Model), and SWAT (Soil and Water Assessment Tool) (Kar *et al*., 2022; Xu *et al*., 2019; Avwunudiogba & Hudson, 2014; Márquez & Guevara-Pérez, 2010). Novitasari *et al*. (2019) implemented the USLE model to predict erosion rates at a watershed scale in Jember Regency - East Java Province. Yanti *et al*. (2020) estimated erosion on post-mining land in East Kalimantan using the USLE model. Agustina & Dewi (2020) used the USLE model for erosion analysis on oil palm land in Muara Enim Regency. In Indonesia, the USLE model is a reference in erosion analysis to assess land suitability for the development of agricultural crops (Ritung *et al*., 2011).

Several researchers in the world have used remote sensing data and the USLE model for erosion analysis. El Jazouli *et al*. (2017) used the USLE model and utilized Landsat 8 OLI and ASTER GDEM satellite imagery to analyze the potential for erosion in the Ikkour Watershed - Morocco. Životić *et al*. (2012) assessed the erosion rate in the Nisava – Serbia watershed using the USLE model and Landsat 7 ETM+ satellite imagery. Suharyanto *et al*. (2013) utilized SPOT satellite imagery and the USLE model to conduct an erosion study in the Lesti Watershed (East Java). Srinivasan *et al*. (2019) used Landsat 8 OLI satellite imagery and the USLE model to predict erosion rates in the Bay of Bengal - India. Gao *et al*. (2017) utilized MODIS satellite imagery and the USLE model to evaluate erosion in Guangdong Province - China.

The utilization of remote sensing data provides excellent accuracy in estimating erosion rates. Xu *et al*. (2019) reported that the use of Landsat 8 OLI satellite imagery provides up to 90% accuracy in erosion analysis. The study by Meinen & Robinson (2021) showed that the use of data from unmanned aerial vehicle (UAV) recordings in erosion analysis provides a deviation of 20% compared to measurement data. Research conducted by Wang *et al*. (2013) showed that the use of Landsat TM satellite imagery provides up to 93% accuracy in erosion analysis compared to measurement results. Furthermore, Arif *et al*. (2017) reported that the use of SPOT 5 satellite imagery provides up to 90.57% accuracy in estimating erosion in the Serang – Kulonprogo watershed.

Besides having good accuracy, the utilization of remote sensing data in erosion analysis provides various advantages, including; erosion rates can be analyzed and mapped quickly at a lower cost than survey methods or direct measurements (Sepuru & Dube, 2018), remote sensing technology can provide data that better influences erosion such as land cover or vegetation, slope, and slope length (Panagos *et al*., 2014), and can be used to monitor erosion rates because it can provide up-to-date and near-real-time data (Senanayake *et al*., 2020).

The Arui watershed (DAS) is one of the main watersheds in Manokwari Regency - West Papua Province which has an area of ± 232 km2. The Arui watershed is one of the main concern watersheds that need to be restored based on the Decree of the Minister of Forestry Number: SK.328/Menhut-II/2009 (Kementerian Kehutanan, 2009). Furthermore, the Watershed and Protected Forest Management Center (BPDASHL) reported that the Arui watershed is one of the watersheds that must be restored due to high erosion rates and sedimentation which tends to increase (Ransiki, 2017). The existence of deforestation in the Arui watershed in the period 2006 – 2016 has resulted in the forest area in the Arui watershed decreasing by 4.71% at a rate of 121.80 ha/year (Arifin *et al*., 2019) thereby contributing significantly to an increase erosion rate and sedimentation in the Arui watershed.

Considering the conditions discussed above, this study was aimed to analyze the potential for erosion in the Arui watershed in Manokwari District - West Papua Province through the utilization of the USLE model based on remote sensing data.

2. MATERIALS AND METHODS

This research was conducted in the Arui Watershed - Manokwari Regency - West Papua Province from April to July 2022. The research location is presented in Figure 1. In general, this research consisted of 3 (three) main stages, namely; data inventory, data analysis, and erosion rate estimation.

2.1. Data Inventory

This stage aims to collect the data needed for erosion analysis, namely; texture data and soil organic content, digital elevation model (DEM) format of the topographical data, rain data from satellite observations CHIRPS (Climate Hazards Group Infrared Precipitation with Stations) recorded from 1981 to 2021, and Sentinel 2 satellite imagery recorded from 2021.

Texture data and soil organic content were obtained from the ISRIC (International Soil Reference and Information Center) via https://soilgrids.org, and rain data from satellite observations (CHIRPS) can be obtained via https://data.chc.ucsb.edu/products/CHIRPS-2.0/, topographic data in DEM format were obtained from the Geospatial Information Agency (BIG) via https://tanahair.indonesia.go.id/demnas/#/, and Sentinel 2 satellite imagery can be retrieved via https://apps.sentinel-hub.com/eo-browser/.

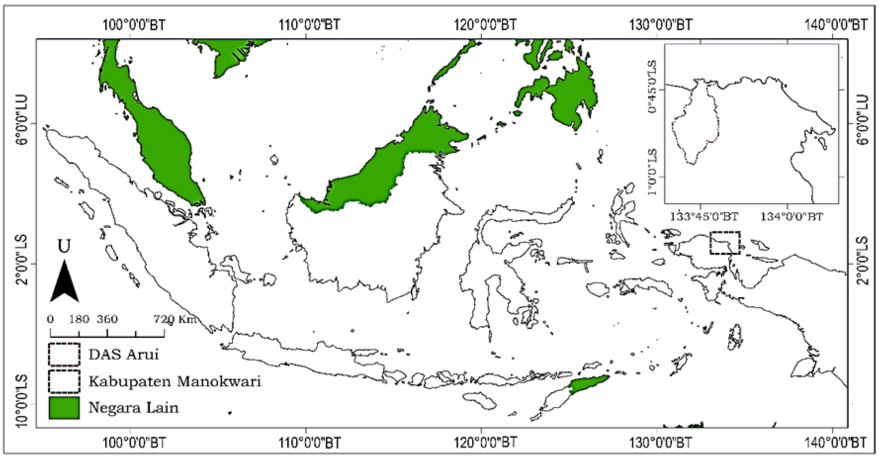


Figure 1. Research location (red-bordered area in the inzet).

2.2. Data Analysis

This stage aims to calculate the parameters that affect erosion, namely; factors of length and slope, erosivity of rain, soil erodibility, as well as factors of plant management and soil conservation techniques.

2.1.1 Factors of Length and Slope

The DEM data and calculation using the following equation (Wischmeier & Smith, 1978) was used to analyze length and slope factors index (*LS*):

$$LS = \left(\frac{\lambda}{22{,}13}\right)^{m} x(65{,}4 sin^2\beta + 4{,}5 sin\beta + 0.0654) \quad (1)$$

where λ is length of slope (feet), β is slope (^{o}); m = 0,5 if $\beta > 5\%$, m = 0,4 if $3\% < \beta < 5\%$, m = 0,3 if $1\% < \beta < 3\%$, and m = 0,2 if $\beta < 1\%$.

2.1.2. Rain Erosivity

Erosivity of rain is a driving force that can cause the transport of soil particles. Rain erosion was analyzed using CHIRPS data and calculated using the Wischmeier-Smith equation (Sotiropoulou *et al*., 2011):

$$R = 10^{\left(\left(1{,}93 \log_{10} \sum \frac{P_i^2}{P}\right) - 1{,}52\right)} \tag{2}$$

where R is the erosivity of the rain (MJ.mm.ha^{-1}.year^{-1}), P_i is the average monthly rainfall (mm), and P is the annual rainfall (mm).

2.1.3. Soil Erodibility

The soil's susceptibility to erosion is determined by its erodibility; the greater the erodibility, the simpler it is to erode. Soil erodibility was analyzed using a soil texture approach using the following Sharply – Williams equation (Djuwansah & Mulyono, 2017; Sharpley & Williams, 1990):

$$K = 0{,}2 + \left(0{,}3\, e^{a} \times \left(\frac{sd}{cl+st}\right)^{0{,}3} \times (1-b) \times (1-c)\right) \tag{3}$$

$$a = \left(-0{,}0256\, sd \left(1 - \frac{st}{100}\right)\right) \tag{4}$$

$$b = \frac{0{,}25\, OM}{OM + e^{(3{,}72 - 2{,}95\, OM)}} \tag{5}$$

$$c = \frac{0{,}75\left(1-\frac{sd}{100}\right)}{\left(1-\frac{sd}{100}\right) + e^{\left(22{,}95\left(1-\frac{sd}{100}\right) - 5{,}51\right)}} \tag{6}$$

where K is soil erodibility (ton.MJ^{-1}.mm^{-1}), sd is sand content (%), st is silt content (%), cl is clay content (%), and OM soil organic content (%).

Soil organic content can be analyzed based on the relationship between soil carbon stock and soil sample thickness using equation (7) (Bernoux *et al*., 1998):

$$E = \rho s \times t \times OM \tag{7}$$

where E is soil carbon stock (ton/ha), ρs is soil density (g/cm^3), and t is soil sample thickness (cm).

2.1.4. Crop Management Factors and Soil Conservation Techniques

Crop management factors and conservation techniques were analyzed using plant indexes obtained from remote sensing data and calculated according equation (8) (Durigon *et al*., 2014):

$$C = \frac{1 - NDVI}{2} \tag{8}$$

where C is the crop management factor, and $NDVI$ is the Normalized Difference Vegetation Index or normalized vegetation index (Liu & Mason, 2009) calculated using equation (9):

$$NDVI = \frac{\rho_{NIR} - \rho_{RED}}{\rho_{NIR} + \rho_{RED}} \quad (9)$$

where ρ_{NIR} is the value of near-infrared reflectance band, and ρ_{RED} is the value of red band reflectance. On the Sentinel 2 satellite imagery, the *NDVI* is calculated using equation (10) (The European Space Agency, 2018):

$$NDVI = \frac{\rho_8 - \rho_4}{\rho_8 + \rho_4} \quad (10)$$

where ρ_8 is the value for the reflectance band 8, and ρ_4 is the value for the reflectance band 4.

The basic value of the soil conservation technique factor (*P*) is 1 which is given for land without conservation measures.

2.3. Erosion Rate Estimation

The erosion rate is analyzed using the USLE model which is calculated using equation (11) (Ritung *et al*., 2011; Wischmeier & Smith, 1978):

$$A = R \times K \times LS \times C \times P \quad (11)$$

where *A* is the amount of soil lost (t.ha^{-1}.y^{-1}).

3. RESULTS AND DISCUSSION

Based on the interpretation and analysis of DEM data released by BIG, the Arui watershed is at an altitude of 4 – 1663 meters above sea level with a slope of 0^{o} – 75.32^{o}. Based on the results of DEM interpretation and analysis, the topographical conditions of the Arui watershed are presented in Figure 2.

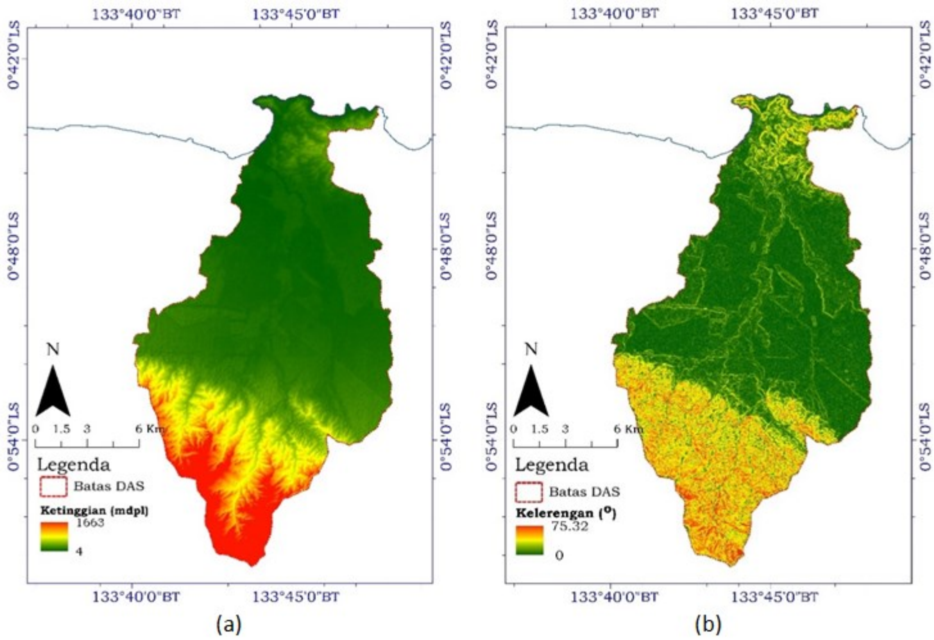


Figure 2. Topography of the Arui watershed; (a) altitude, (b) slope

From the results of DEM data analysis and the Wischmeirer-Smith method, the Arui watershed has an average length and slope factor value of ±11.50. The length factor index and slope of the Arui watershed from DEM analysis and the Wischmeirer-Smith method are presented in Figure 3.

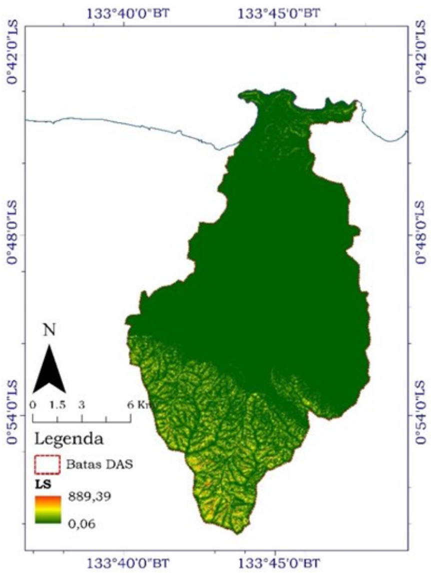


Figure 3. Length factor index and slope of the Arui watershed

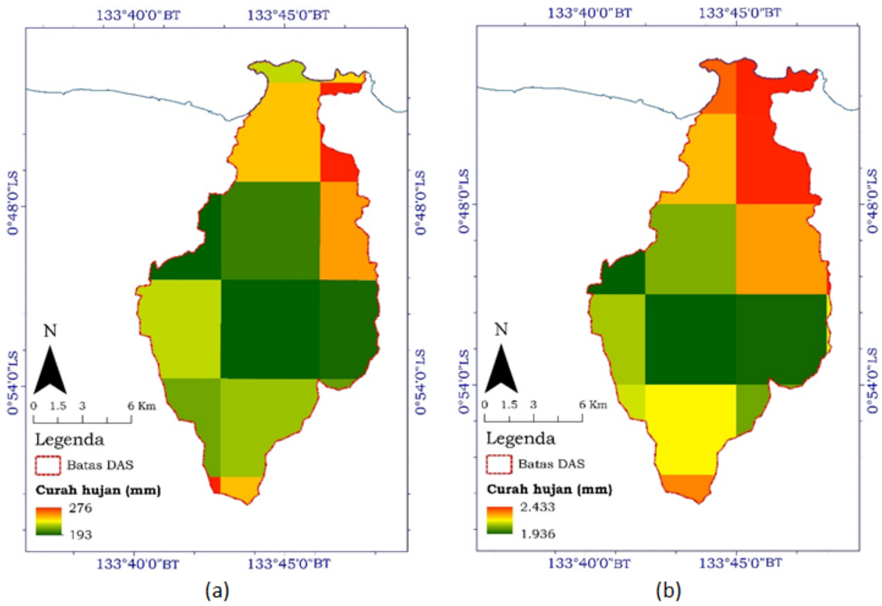


Figure 4. Rainfall in the Arui watershed (a) monthly rainfall and (b) annual rainfall

The annual rainfall in the Arui watershed is based on the results of CHIRPS data analysis recording for 1981 – 2021 of 2,171 mm and the average monthly rainfall is 209 mm. Meanwhile, the average annual erosivity in the Arui watershed, based on analysis of CHIRPS data recorded in 1981 – 2021 and the Wischmeirer-Smith method, is 207.58 MJ.mm.ha^{-1}.h^{-1}. The distribution of annual rainfall and monthly rainfall in the Arui watershed from the CHIRPS data analysis is presented in Figure 4. Meanwhile, the erosivity in the Arui watershed from the CHIRPS data analysis and the Wischmeirer-Smith method is presented in Figure 5.

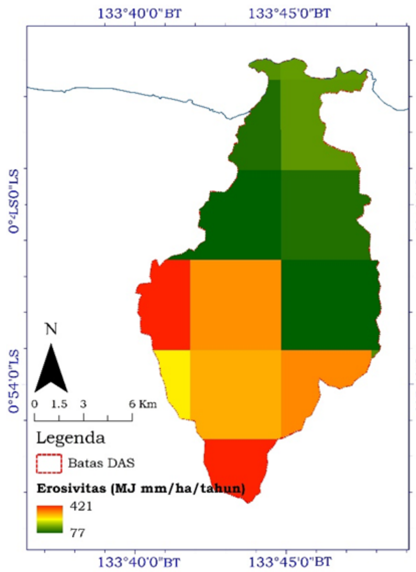
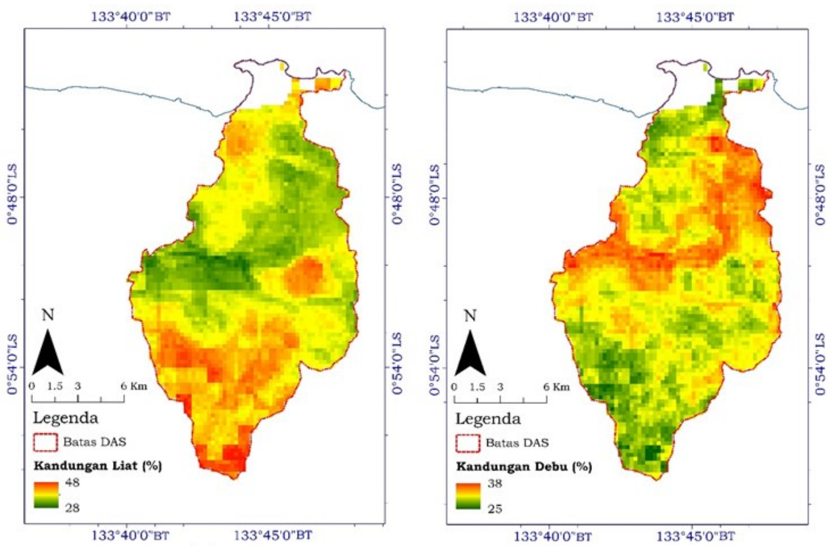


Figure 5. Erosivity in the Arui watershed

Based on data from ISRIC, the soil in the Arui watershed generally has an average clay content of ±377 g/kg or 37.7%, a dust content of ±318 g/kg or 31.8%, a sand content of ±303 g/kg or 30.3%, and an organic carbon content of 10.29%. The soil texture in the Arui watershed is dominated by clay loam and clay. Soil conditions in the Arui watershed based on data from ISRIC are presented in Figure 6. The average soil erodibility in the Arui watershed based on the soil texture approach and the Sharply – Williams method is 0.037 t.ha.h.ha^{-1}.MJ^{-1}.mm^{-1}. The soil erodibility in the Arui watershed is distributed spatially as presented in Figure 7.

Based on the analysis of Sentinel 2 satellite imagery recorded in 2021, the average vegetation index (NDVI) value in the Arui watershed is 0.74, and the average plant management factor value is 0.13. The condition of land cover in the Arui watershed from Sentinel 2 satellite imagery, distribution of vegetation index, and crop management factors are presented in Figure 8.



(a) (b)

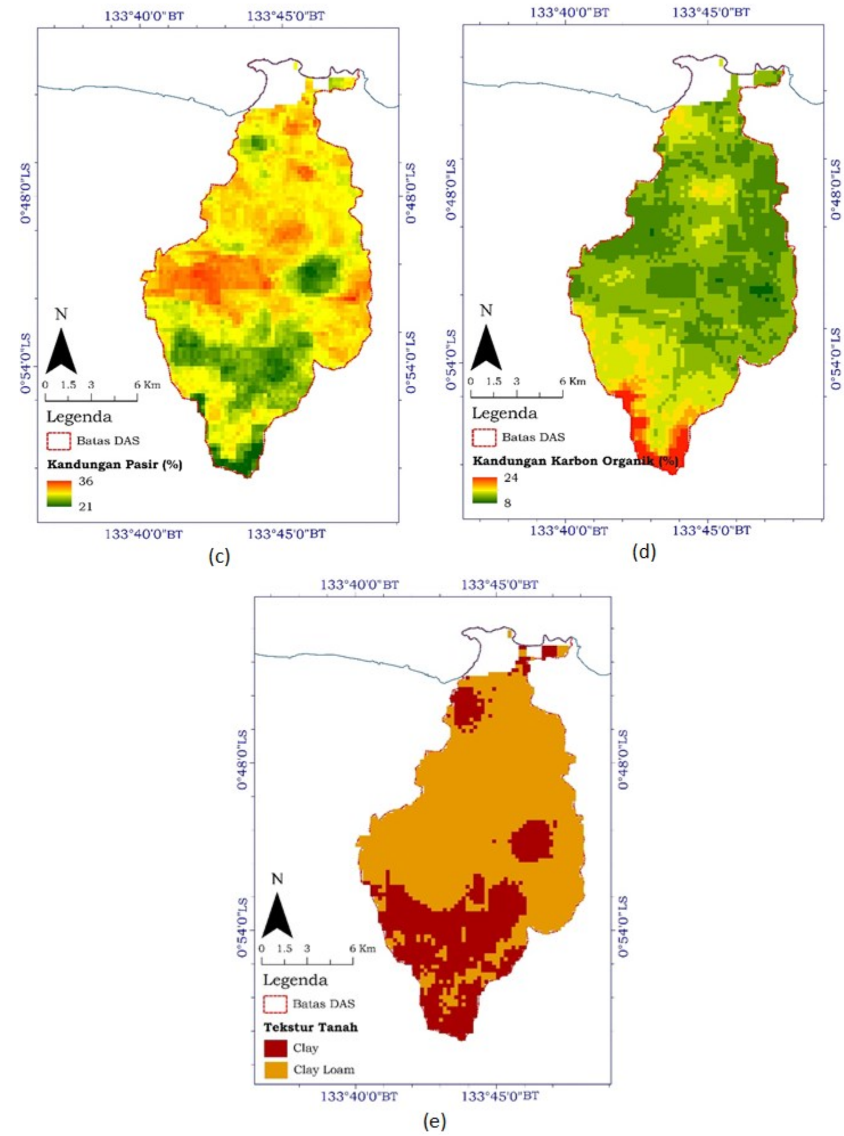


Figure 6. Soil conditions in the Arui watershed; (a) clay content, (b) silt content, (c) sand content, (d) organic content, (e) soil texture

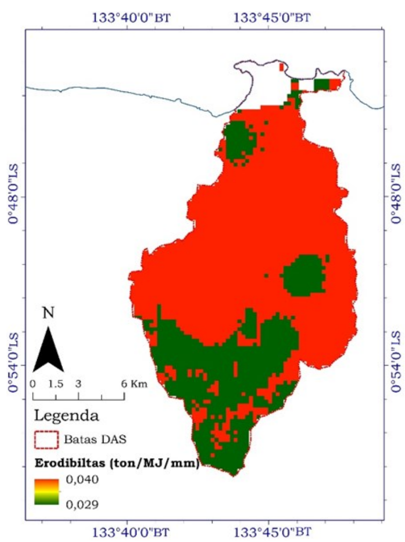


Figure 7. Soil erodibility of the Arui watershed

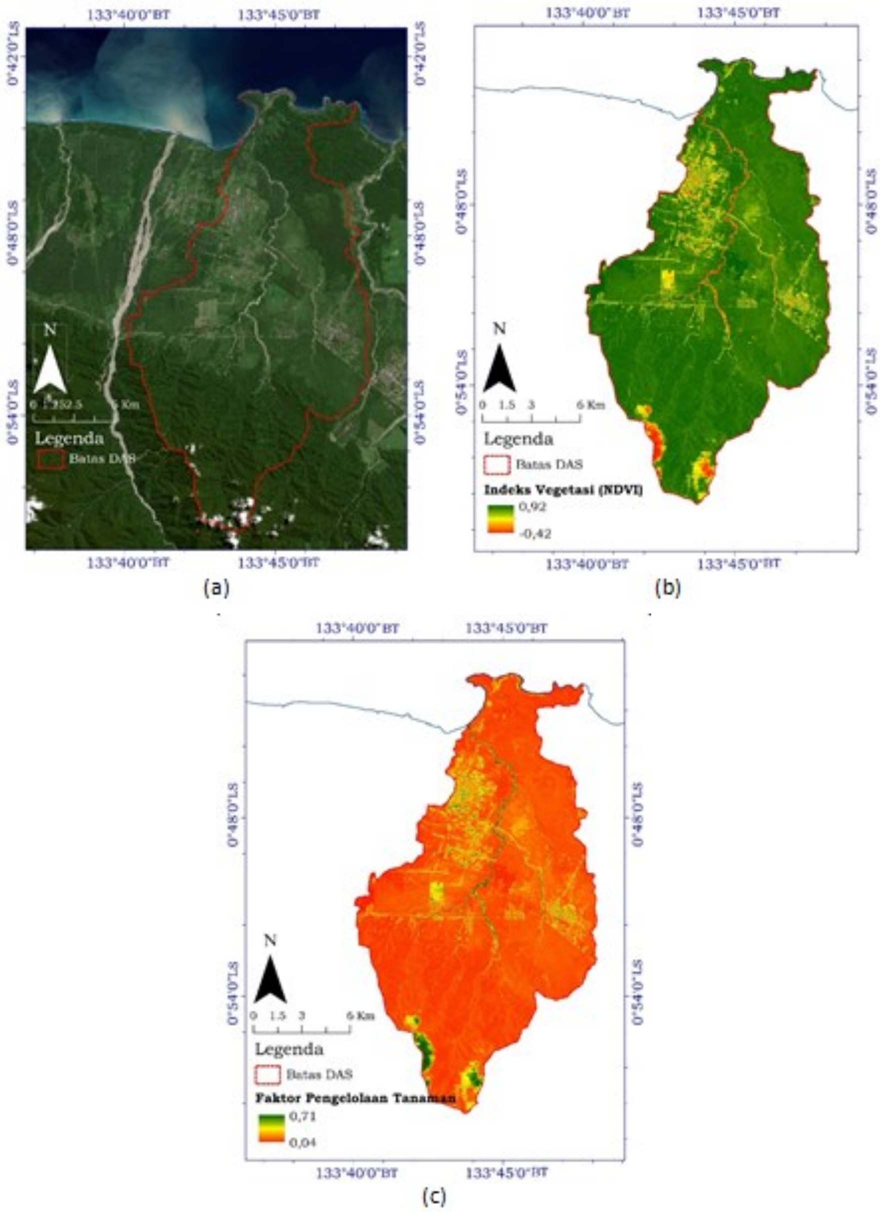


Figure 8. Condition of the Arui watershed; (a) Satellite imagery, (b) Vegetation index (NDVI), (c) Crop management factors

The results of erosion analysis using the USLE method show that the average erosion rate in the Arui watershed is quite low, namely 15 $t.ha^{-1}.y^{-1}$ or 3,480 ton/year. Referring to the Regulation of the Minister of Forestry No. P.32/Menhut-II/2009, the Arui Watershed has a mild erosion hazard. The low rate of erosion that occurs is suspected because the land cover of the Arui watershed is still dominated by vegetation or plants, so that the erosivity of rainwater that falls in the watershed can still be reduced properly. The crushing power and carrying capacity of the soil by rainwater can be reduced or minimized by the vegetation that grows on it (Arsyad, 2006). The erosion rate in the Arui watershed is depicted in Figure 9.

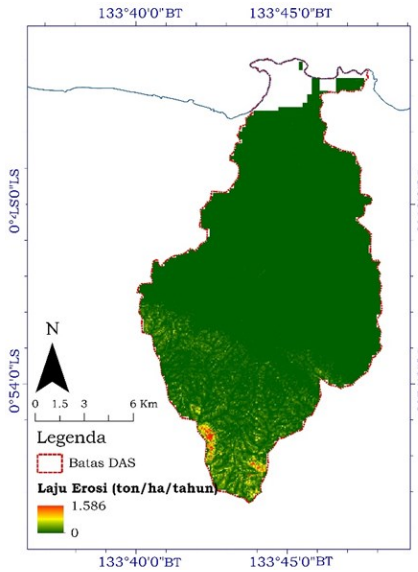


Figure 9. Spatial distribution of erosion rates in the Arui watershed

When referring to the guidelines for determining the tolerable soil loss (TSL) for soils in Indonesia (Arsyad, 1989), the permitted erosion rate for the Arui watershed is 9.6 tons/ha/year because the soil in Manokwari Regency generally has shallow soil with a depth of 15 – 30 cm (Mofu *et al*., 2019). So that the erosion rate in the Arui watershed exceeds the tolerance rate of erosion. This is relevant to the BPDASHL report by Ransiki (2017) which states that the Arui watershed has high erosion rate. Therefore it is compulsory to carry out conservation efforts to control the rate of erosion in the Arui watershed.

4. CONCLUSIONS AND SUGGESTIONS

Grounded on the discussion and analysis of remote sensing data and the USLE model, it is concluded that the rate of erosion in the Arui watershed exceeds the threshold for the rate of erosion that can be tolerated, so conservation efforts are necessary. In addition, it is crucial to test the accuracy of erosion analysis results based on remote sensing data compared to survey methods or direct measurements. This method can eventually become an alternative solution in analyzing the rate of soil erosion quickly at a lower cost.

REFERENCES

Agustina, H., & Dewi, V.A.K. (2020). Analisis erosi metode USLE pada lahan sawit Kabupaten Muara Enim, *Jurnal Teknik Pertanian Lampung*, ***9***(3), 157 - 162.

Arif, N., Danoedoro, P., & Hartono, H. (2017). Remote sensing and GIS approaches to a qualitative assessment of soil erosion risk in Serang watershed, Kulonprogo, Indonesia. *Geoplanning: Journal of Geomatics and Planning*, ***4***(2), 131–142. https://doi.org/10.14710/geoplanning.4.2.131-142

Arifin, H., Heatubun, C.H., & Wahyudi. (2019). Analisis kawasan hutan dan tutupan hutan pada tiga daerah aliran sungai di Kabupaten Manokwari. *Cassowary*, ***2***(1), 49-67. https://doi.org/10.30862/casssowary.cs.v2.i1.22

Arsyad, S. 1989. *Konservasi Tanah dan Air*. IPB Press. Bogor.

Arsyad, S. 2006. *Konservasi Tanah dan Air*. IPB Press. Bogor. 396 hal.

Avwunudiogba, A., & Hudson, P.F. (2014). A review of soil erosion models with special reference to the needs of humid tropical mountainous environments. *European Journal of Sustainable Development*, ***3***(4), 299–310. https://doi.org/10.14207/ejsd.2014.v3n4p299

Ransiki, R. (2017). *Laporan Monitoring dan Evaluasi Pengelolaan DAS Wosi Tahun 2016*. Kementerian Lingkungan Hidup dan Kehutanan. Jakarta

Bernoux, M., Arrouays, D., Cerri, C., Volkoff, B., & Jolivet, C. (1998). Bulk densities of Brazilian Amazon soils related to other soil properties. *Soil Science Society of America Journal*, ***62***(3), 743–749.

Djuwansah, M.R., & Mulyono, A. (2017). Assessment model for determining soil erodibility factor in Lombok Island. *Riset Geologi dan Pertambangan*, ***27***(2), 133–143. https://doi.org/10.14203/risetgeotam2017.v27.417

Durigon, V.L., Carvalho, D.F., Antunes, M.A.H., Oliveira, P.T.S., & Fernandes, M.M. (2014). NDVI time series for monitoring RUSLE cover management factor in a tropical watershed. *International Journal of Remote Sensing*, ***35***(2), 441–453. https://doi.org/10.1080/01431161.2013.871081

El Jazouli, A., Barakat, A., Ghafiri, A., El Moutaki, S., Ettaqy, A., & Khellouk, R. (2017). Soil erosion modeled with USLE, GIS, and remote sensing: A case study of Ikkour watershed in Middle Atlas (Morocco). *Geoscience Letters*, ***4***(1), 12p. https://doi.org/10.1186/s40562-017-0091-6

Gao, F., Wang, Y., & Yang, J. (2017). Assessing soil erosion using USLE model and MODIS data in the Guangdong, China. *IOP Conference Series: Earth and Environmental Science*, ***74***(1), 012007. https://doi.org/10.1088/1755-1315/74/1/012007

Kar, S.K., Kumar, S., Sankar, M., Patra, S., Singh, R.M., Shrimali, S.S., & Ojasvi, P.R. (2022). Process-based modelling of soil erosion : Scope and limitation in the Indian context. *Current Science*, ***122***(5), 533–541.

Karydas, C.G., Panagos, P., & Gitas, I.Z. (2014). A classification of water erosion models according to their geospatial characteristics. *International Journal of Digital Earth*, ***7***(3), 229–250. https://doi.org/10.1080/17538947.2012.671380

Kementerian Kehutanan. (2009). *Keputusan Menteri Kehutanan Republik Indonesia Nomor: SK.328/Menhut-II/2009 Tentang Penetapan Daerah Aliran Sungai (DAS) Prioritas Dalam Rangka Rencana Pembangunan Jangka Menengah (RPJM) Tahun 2010 - 2014*. Kementerian Kehutanan Republik Indonesia. Jakarta.

Kementerian Kehutanan. (2009). *Peraturan Menteri Kehutanan Republik Indonesia Nomor: P.32/Menhut-II/2009 Tentang Tata Cara Penyusunan Rencana Teknik Rehabilitasi Hutan dan Lahan Daerah Aliran Sungai (RTkRHL-DAS)*. Kementerian Kehutanan Republik Indonesia. Jakarta.

Mofu, Y., Lindongi, LE., Tukayo, R.K., & Suparno, A. (2019). Analisis daya dukung lahan pertanian di Kampung Susweni Distrik Manokwari Timur. *Agrotek*, ***7***(2), 24 - 32.

Liu, J.G., & Mason, P.J. (2009). *Essential Image Processing and GIS for Remote Sensing* (1st ed.). Wiley & Sons, Ltd.

Márquez, A.M., & Guevara-Pérez, E. (2010). Comparative analysis of erosion modeling techniques in a basin of Venezuela. *Journal of Urban and Environmental Engineering*, ***4***(2), 81–104. https://doi.org/10.4090/juee.2010.v4n2.081104

Meinen, B.U., & Robinson, D.T. (2021). Agricultural erosion modelling: Evaluating USLE and WEPP field-scale erosion estimates using UAV time-series data. *Environmental Modelling and Software*, ***137***(January), 10 p. https://

doi.org/10.1016/j.envsoft.2021.104962

Novitasari, Rohman, M.H., Ambarwati, A.A., & Indarto, I. (2019). Aplikasi USLE dan GIS untuk prediksi laju erosi di wilayah DAS Brantas. *Jurnal Teknik Pertanian Lampung*, ***8***(2), 76 - 84.

Panagos, P., Karydas, C., Borrelli, P., Ballabio, C., & Meusburger, K. (2014). Advances in soil erosion modelling through remote sensing data availability at European scale. *Second International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2014)*, *9229*(September), 10 p. https://doi.org/10.1117/12.2066383

Raza, A., Ahrends, H., Habib-Ur-rahman, M., & Gaiser, T. (2021). Modeling approaches to assess soil erosion by water at the field scale with special emphasis on heterogeneity of soils and crops. *Land*, ***10***(4), 35 p. https://doi.org/10.3390/land10040422

Ritung, S., Nugroho, K., Mulyani, A., & Suryani, E. (2011). *Petunjuk Teknis Evaluasi Lahan untuk Komoditas Pertanian* (2nd ed.). Balai Besar Penelitian dan Pengembangan Sumberdaya Lahan Pertanian.

Senanayake, S., Pradhan, B., Huete, A., & Brennan, J. (2020). A Review on assessing and mapping soil erosion hazard using geo-informatics technology for farming system management. *Remote Sensing*, ***12***(24), 1–25. https://doi.org/10.3390/rs12244063

Sepuru, T. K., & Dube, T. (2018). An appraisal on the progress of remote sensing applications in soil erosion mapping and monitoring. *Remote Sensing Applications: Society and Environment*, ***9***, 9 p. https://doi.org/https://doi.org/10.1016/j.rsase.2017.10.005

Sharpley, A.N., & Williams, J.R. (1990). EPIC: The erosion-productivity impact calculator. In *U.S. Department of Agriculture Technical Bulletin* (Issue 1768). http://agris.fao.org/agris-search/search.do?recordID=US9403696

Sotiropoulou, A.M., Alexandridis, T., Bilas, G., Karapetsas, N., Tzellou, A., Silleos, N., & Misopolinos, N. (2011). A user friendly GIS model for the estimation of erosion risk in agricultural land using USLE. *Proceedings of The International Conference on Information and Communication Technologies*, 795–801

Srinivasan, R., Singh, S.K., Nayak, D.C., Hegde, R., & Ramesh, M. (2019). Estimation of soil loss by USLE model using remote sensing and GIS Techniques - A case study of coastal Odisha, India. *Eurasian Journal of Soil Science*, ***8***(4), 321–328. https://doi.org/10.18393/ejss.598120

Suharyanto, A., Suhartanto, E., & Pudyono. (2013). The use of satellite remote sensing data and geographic information systems on critical land analysis. *Agrivita*, ***35***(2), 119–126. https://doi.org/10.17503/Agrivita-2013-35-2-p119-126

The European Space Agency. (2018). *Level-2A Algorithm Overview*. https://sentinels.copernicus.eu/web/sentinel/technical-guides/sentinel-2-msi/level-2a/algorithm

USDA (United States Department of Agriculture). (1978). Predicting rainfall erosion losses - A guide to conservation planing. In *USDA Agricultural Handbook **537*** (1st ed., Vol. 1, Issue 1). United States Department of Agriculture.

Wang, L., Huang, J., Du, Y., Hu, Y., & Han, P. (2013). Dynamic assessment of soil erosion risk using landsat TM and HJ satellite data in Danjiangkou Reservoir Area, China. *Remote Sensing*, ***5***(8), 3826–3848. https://doi.org/10.3390/rs5083826

Wischmeier, W.H., & Smith, D.D. (1978). *Predicting Rainfall Erosion Losses*. In *USDA* (Vol. 1, Issue 1).

Yanti, D.F., Mansur, I., Rusdiana, O., & Kirmi, H. (2020). Pendugaan laju erosi tanaman serai wangi (*Cymbopogon nardus* L.) pada lahan pasca tambang. *Jurnal Teknik Pertanian Lampung*, ***9***(1), 55 - 62.

Xu, H., Hu, X., Guan, H., Zhang, B., Wang, M., Chen, S., & Chen, M. (2019). A remote sensing based method to detect soil erosion in forests. *Remote Sensing*, ***11***(5), 19 p. https://doi.org/10.3390/rs11050513

Životić, L., Perović, V., Jaramaz, D., Dordević, A., Petrović, R., & Todorović, M. (2012). Application of USLE, GIS, and Remote sensing in the assessment of soil erosion rates in Southeastern Serbia. *Polish Journal of Environmental Studies*, ***21***(6), 405–4011.