Advances in Biological Sciences Research, volume 17
International Conference on Tropical Agrifood, Feed and Fuel (ICTAFF 2021)

Implementation of Land Rehabilitation to Reduce Soil Erosion and Surface Runoff by Sengon (*Falcataria moluccana*) and Jabon (*Antocephalus cadamba*) Plantation

Sri Sarminah*, Karyati, T. Hartono, and F. Afandi

Faculty of Forestry, University of Mulawarman, Samarinda, East Kalimantan, Indonesia 75119
**Corresponding author. Email: srisarminah.fahutanunmul2017@gmail.com*

ABSTRACT

Land productivity and stability can be reduced due to damaged watershed systems and increased surface runoff and erosion in soil. Unsustainable land management is one of the factors affecting land degradation, most of the decreased quality of the land is caused by soil erosion. Implementations of land rehabilitation and soil conservation especially to prevent the soil from erosion rates in some degraded land. The aim of this study was to determine the amount of surface runoff and erosion which potentially occurred on the vegetatively rehabilitated land by sengon and jabon plantation. The study was established on open land in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, East Kalimantan. The erosion measuring plots (EMP) were prepared at open land with the presence of sengon and jabon at different slope classes. Two plots with the size of 10 m x 4 m were made for each combination used. At the lowest part of the EMP, a paralon pipe was then installed to channel surface runoff and eroded soil into the storage drum. Hydro-orological parameters, including rainfall, surface runoff (only water mass measured), potential erosion rate (A), erosion hazard class (EHC), erosion hazard level (EHL), and depth of soil solum, were observed. The amount of surface runoff at the land planted with sengon and jabon showed different values regarding the slope classes and plant age. At the slope classes of rather steep, the surface runoff was lower than that of steep even at both 1 year and 2 years of planting age. The potential erosion that occurred in the area planted with sengon in the slope class of rather steep and steep at plant age was still lower than 15 ton ha-1year-1, indicating that the erosion hazard level was low. A similar condition was found at land planted with jabon at rather steep. On the other hand, land planted with jabon in steep slope classes both 1 year and 2 years showed potential erosion > 15 ton ha-1year-1 (EHL was low). This study suggested that sengon and jabon could be potentially utilized to reduce runoff rates and eroded soil mass for water and soil conservation in the future.

***Keywords**: Rehabilitation, Soil erosion, Surface runoff, Falcataria moluccana), Antocephalus cada*

1. INTRODUCTION

The tropical rainforest of Indonesia is considered the second largest forest area in the world. It has been estimated to possess 94.1 million hectares [1]. According to the regional spatial plan of East Kalimantan in 2016, this province has one of the biggest forest territories in Indonesia with total hectares of 8.3 million. However, forest quality is recently reduced due to an increase in the human population and their several activities such as mining or land clearing for agriculture purposes. It strongly contributes to causingnegative environmental impacts, including a reduction in forest quality which naturally provides a comfortable habitat for rare endemic species of flora and fauna in this province. Furthermore, it can potentially injure the plant biodiversity and source of plasma. On the other hand, land productivity and stability can be reduced due to damaged watershed systems and increased surface runoffand erosion in soil.

Soil erosion potential is influenced by several factors including vegetation development [2]. In order todecrease the risk of soil erosion rehabilitated forest landshave to be intensively managed for at least the first 5 years especially in relation to land preparation and the intensity of vegetation maintenance. The land rehabilitation process must initially be introduced to control surface water flow [3]. The plants grow and provide coverage to protect soil surfaces from excessive erosion.

Unsustainable land management is one of the factors affecting land degradation. Most of the decreased quality of the land is caused by soil erosion. Rainfall, slope, soil type, and land cover reportedly affected the intensity of soil erosion [4]. To prevent and control the soil in the land with a high risk of degradation, especially in the land area possessing high steep slopes and left conditions, the attempt to avoid and surprise the rate of erosion must be

Copyright © 2022 The Authors. Published by Atlantis Press International B.V.
This is an open access article distributed under the CC BY-NC 4.0 license -http://creativecommons.org/licenses/by-nc/4.0/.

immediately done [5]. In principle, soil erosion cannot be eliminated. One of the alternatives to prevent such a problem is using a vegetative method. [6] Daswir (2010) reported that utilization of fast-growing tree species was effective in soil conservation to protect the surface runoff and erosion. This method was done by planting annual crops or perennials on the land. Nevertheless, good land rehabilitation and soil conservation (LRSC) activities should select the appropriate fast-growing plants with high adaptability.Sengon *(Falcataria moluccana* Miq. Barneby andJ.W. Grimes) is a fast-growing plant commonly grown inforest plantations to produce wood for paper production purposes. Its leaves with the faded green color indicated its ability to absorb nitrogen and carbon dioxide at the same time during photosynthesis. Sengon root contains nodules due to its symbiosis with rhizobium bacteria which is beneficial for nutrient absorption in the soil. Thepresence of root nodules gives advantages to improve thesoil porosity and absorb some nitrogen that enhances thesoil to become more fertile. [7] Swestiani and Purwaningsih (2013) reported that the mean annual diameter increment of sengon grown on an agroforestry system and monoculture system were 5.25 cm $year^{-1}$ and 3.20 cm $year^{-1}$ respectively.

Jabon *(Anthocephalus cadamba)* is a fast-growing plant of forest plantation with easy cultivation and without additional treatment because of its good adaptability in the local environment. It can grow largely having a straight wood which produces a high volume compared to other plant species. It has been found to possess low pests and disease attracts. Moreover, it can adapt well to the various types of land, and farmers commonly utilized jabon to improve soil fertilization. The average of its MAI was reported to be close to 6.13 cm $year^{-1}$ [8].

Implementations of land rehabilitation and soil conservation especially to prevent the soil from erosion rates in some degraded Open land have been reported by Hairiah et al. (2004) that the 5 year-old sengon developed a shallow root system, with about 50% of the main root growing horizontally in the upper 0-30 cm of the soil [9]. Respons of jabon seed from many sources of Indonesian to dry and wet treatments [10]. The influence of sand clay on the growth of sengon [11], intensive monoculture system, and conventional monoculture in the development of sengon plantation forest [12]. The potential degraded forest ecosystem recovery was shown by cover crops and fast-growing species plant and undergrowths, decreasing surface runoff and soil erosion rate and its erosion hazard [13]. Sengon - peanut and jabon – soybean agroforestry is suitable to be implemented for rehabilitation and soil conservation of degraded land [14,15].

The aim of this study was to determine the amount of surface runoff and erosion which potentially occurred on the vegetatively rehabilitated land by sengon and jabon plantation. The results of this study will be expected to provide the best method to prevent erosion and runoff for soil conservation and management of the degraded land in the future.

2. MATERIALS AND METHODS

2.1. Study area

This study was conducted in the Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, East Kalimantan Province, as shown by Figure 1land in the educational forest was selected to perform all experiments in this study while each research activity was carried out for 6 (six) months, start from June to December 2018.

2.2. Determination of research location and installation of ombrometer

The research location in this study was selected according to the field orientation. Sengon (*Falcataria moluccana*) and jabon (*Antocephalus cadamba*) plants were planted at different slope classes (rather steep (15 <25%) and steep (25-40%)). The installation of ombrometers was done in a shade-free area.

2.3. Preparation of erosion measuring plot

The erosion measuring plots (EMP) were prepared at open land with the presence of sengon and jabon at different slope classes. The combination of each the experiment was summarized in Table 1. Two plots with the size of 10 x 4 m^2 were made for each combination used. At the lowest part of the EMP, a paralon pipe was then installed to channel surface runoff and eroded soil into the storage drum

2.4.Analysis of soil properties

The analysis of soil properties was conducted in the Laboratory of Soil Science, Research Center of Tropical Forest, Mulawarman University.

2.5.Data analysis using hydro-orological parameters

Hydro-orological parameters, including rainfall, surface runoff (only water mass measured), potential erosion rate (A), erosion hazard class (EHC), erosion hazard level (EHL), and depth of soil solum, were observed. The primary data collected from those parameters were ready for analysis. In addition, secondary data was used to support the primary data for further calculation. The results obtained from the calculation of potential erosion (A) and the depth of soil solum were then grouped into the category of erosion hazard classes and erosion hazard levels (Table 2)

3. RESULTS AND DISCUSSION

3.1. Description of research location

The educational Forest of Forestry Faculty, Mulawarman University which is located at Lempake District (EFFM) is also known as the Unmul Samarinda Botanical Garden (KRUS). Particularly, it is located among the Karang Mumus River Basin in Samarinda City, East Kalimantan Province. Geographically, EFFM is located between 0º25´10´´ - 0º25´24´´ in south latitude (LS) and 117º14´00´´ - 117º 14´14´´ east longitude (BT). EFFM has a natural ecosystem with low land tropical rainforest at an altitude of 50 meters above sea level. The forest community was dominated by the Dipterocarpaceae family, including *Shorea* sp., *Anisoptera* sp., *Dipterocarpus* sp., *Hopea* sp., *Vatica* sp., and *Cotylelobium* sp. After being burned by fires in 1983, 1993, and 1998, most of the vegetation turned into young secondary forests. Currently, it is considered the old secondary forest that leads to achieving climax forest succession [17].

Based on the analysis of rainfall observation from the Meteorology, Climatology and Geophysics Agency (BMKG) in Samarinda, Lempake Sub-watershed from 2008 to 2017 showed 2447.07 mm year^{-1} of annual rainfall followed by a monthly rainfall average of 203.92 mm month^{-1}. Based on the Schmidt-Ferguson climate classification system (1951), the Q (Quotient) value reached 4.71% which was classified into climate type. It also indicated that the area was very wet with tropical rainforest vegetation.

3.2. Physical properties of soil

One of the most important physical properties of soil affecting erosion is soil erodibility. The high value of the erodibility demonstrated that soil is more sensitive to erosion [18]. [19] Stated that soil properties affecting erosion were (a) texture, (b) structure, (c) organic matter, (d) depth, (e) soil layer properties, and (f) soil fertility rate. The texture is the size of the grain and the proportion of the size group of primary grains of mineral soil. Coarse-textured soils such as sand and gravel sand have a high infiltration capacity. When these types of soil have a deep profile, erosion can be neglected. Fine sand-textured soil also has a high infiltration capacity. However, fine grains will be easily transported when surface runoff occurs in this soil [20]. The soil texture at the research location is presented in Table 3.

The results obtained from laboratory analysis showed that the type of soil texture found in the study site was sandy loam. The data in Table 2 were in line with the finding reported by [20] that clay had high cohesion potential due to the availability of large amounts of clay colloids.

3.3. Rainfall surface runoff and potential erosion rate

During 3 months of the research experiments in the EFFM area, 32 times of total rainfall were found. The rainfall ranged from 5 to 57 mm, and the sum of rainfall was 833 mm. Estimation of surface runoff rate (m^3 ha^{-1} year^{-1}) and potential erosion rate (ton ha^{-1} year^{-1}) of vegetatively rehabilitated land by sengon and jabon was presented in Table 4.

The results revealed that a significant difference in the total surface runoff and eroded soil mass was found due to slope class and the different ages of each plant. This phenomenon was influenced by several topographic factors, such as slope type, slope length, and slope shape. The steeper slope could increase the amount of surface runoff as an increase in kinetic energy to transport the soil grains. The results shown in Table 4 demonstrated that the EMP I (rather steep) planted with sengon and jabon at the age of 1 year produced a low amount of surface runoff and soil mass eroded compared to the EMP III (steep) even with the same age of the plant. The EMP II (rather steep) planted with sengon and jabon at the age of 2 years also showed smaller surface runoff and soil mass eroded than that of the EMP IV (steep) at the same plant age (2 years). Although different slope classes, plant age, and rainfall were considered the common factors influencing soil erosion and runoff, we stated that the canopy shape of the plant, especially jabon due to its high leave shape, could potentially protect soil from direct raindrops, contributing to decreased soil mass transported by rain.

The evaluation of erosion hazard is an assessment to predict the magnitude of soil erosion and its potential hazard to a plot of land. This evaluation was calculated according to the results from the land evaluation and its level. To find out the erosion classification at the level of danger or threat, it could be seen from the level of erosion hazard of land. Then, it should be compared to the level of erosion that can be left (soil loss tolerance) in accordance with the condition of soil solum at the study site. Based on the observation of soil profiles in the research area, it could be concluded that the depth of the land at the site reached > 100 cm. Theoretically, the permissible erosion for soils >100 cm is estimated to be 14 tons ha^{-1} year^{-1} [21]. The soil mass eroded at the EMP III and the EMP IV exceeded the allowed threshold, while at the EMP I and the EMP II, the eroded soil mass could still be tolerated. The erosion hazard index at the EMP I, EMP II, EMP III, and EMP IV was 0.31 (low value), 0.30 (low value), 1.26 (medium value) and 1.14 (medium value), respectively.

The potential of erosion in land planted by sengon and jabon at all slope classes (rather steep and steep) with different plant ages (1 year and 2 years) was still lower than 15 ton ha^{-1} year^{-1}. When it was associated with the depth of the soil solum (> 100 cm), the erosion hazard level (EHL) was very low. On the other hand, land planted by jabon at the steep slope classes both 1 year and 2 years plantation age, erosion potential occurred lower than 15 ton $ha^{-1}year^{-1}$, indicating obtained low value. The summary of potential erosion rate, erosion hazard class, erosion hazard level was shown in Table 5.

3.4. Performance of land rehabilitation and soil conservation using the vegetative method

Land rehabilitation and soil conservation using vegetative techniques have an essential role to control surface runoff and soil erosion, especially in areas having high slopes. Generally, land planted with vegetation could absorb a high amount of water. Water from the rain did not only fall on the surface of the soil directly, but also was blocked by plant bodies such as leaves, stems, and litter, contributing to reducing the number of raindrops. In addition, organic matter, microorganisms, and plant roots had a mutualism symbiosis to increase soil porosity and stabilize soil structure. Vegetation also played a role in maintaining the presence of groundwater, increasing the chances of storing groundwater, and producing a higher infiltration rate.

The vegetative technique is often chosen in the water and soil conservation implementation because it couldsignificantly reduce erosion and sedimentation in some rivers. They also had a cheaper cost compared to other methods. Furthermore, they also could be a good option in watershed management. Among all forest plant species, sengon and jabon received great attention to be used in vegetative soil conservation due to their fast-growing ability. Plant parts could hold the rate of rainwater effectively by reducing the kinetic energy of water grains and releasing soil particles. Water that is available at the tree canopy (interception) could be partially evaporated into the atmosphere. The functionof soil surface protection against the blow of rainwater was very important because the erosion case in Indonesiawas mainly caused by rainwater. The vegetation could highly cover the land which decreased the risk of the destruction of the soil aggregate due to the blow of the rainwater. The stem of the plant could be a barrier to rainwater erosion by seeping the flow of water from the canopy through the stem to the ground. Thus, the kineticenergy was reduced significantly. When the kinetic energy of surface runoff decreases, the material carrying capacity was also reduced and the soil has a high opportunity to absorb water. Some types of plants plantedat a short distance could form a barrier to break the surface runoff. The soil particles moved by water flow during surface runoff could settle under the stem and form a more stable surface runoff field.

4. CONCLUSION

In summary, we found that the amount of surface runoff at the land planted with sengon and jabon showed different values regarding the slope classes and plant age. At the slope classes of rather steep, the surface runoff was lower than that of steep even at both 1 year and 2 years of planting age. The potential erosion that occurred in the area planted with sengon in the slope class of rather steep and steep at plant age was still lower than 15 ton ha-1year-1, indicating that the erosion hazard level was low. A similar condition was found at land planted with jabon at rather steep. On the other hand, land planted with jabon in steep slope classes both 1 year and 2 years showed potential erosion > 15 ton ha-1year-1 (EHL was low). This study suggested that sengon and jabon could be potentially utilized to reduce runoff rates and eroded soil mass for water and soil conservation in the future.

ACKNOWLEDGMENTS

The authors wish to express their thanks to the manager and staff of Educational Forest of Forestry Faculty of Mulawarman University, Lempake District, Samarinda City, East Kalimantan Province for facilitating this research. The authors would also like to acknowledge all of the reviewers for critical review of the manuscript.

REFERENCES

[1] Direktorat Jenderal Planologi Kehutanan dan Tata Lingkungan (PKTL) Kementerian Lingkungan Hidup dan Kehutanan 2019

[2] Dantas de Paula M, Groeneveld J and Hutha A 2015 Tropical forest degradation and recovery in fragmented landscapes-simulating changes in tree community forest hydrology and carbon balance Global Ecol Conserv (3) pp 664-677

[3] Lei H, Peng Z, Yigang H and Yang Z. 2015 Vegetation succession and soil infiltration characteristics under different aged refuse dumps at the Heidaigou opencast coal mine. Global Ecol Conserv 4: 255-263

[4] A'Yunin Q 2008 Prediction of erosion hazard level with USLE method on the eastern slope of Mount Sindoro [Hon. Thesis] Faculty of Agriculture Sebelas Maret University Surakarta [Indonesian]

[5] Sarminah S 2010. Prediction of soil erosion on alang-alang land with vegetative system in Sungai Merdeka village Samboja Kutai Kartanegara Rimba Kalimantan 15(2) [Indonesian]

[6] Daswir. 2010. Role of serai wangi as a conservation plant at cocoa plantation on critical land Bul Littro 21(2) pp 117-128 [Indonesian]

[7] Swestiani D, Purwaningsih S. 2013. Production of groundnut (Arachis hypogaea L.) in agroforestry based sengon and manglid timbers. Agroforestry 1(2) pp 71-82

[8] Wahyudi dan Pamoengkas. 2013. Pertumbuhan diameter tanaman Jabon (Anthocephallus cadamba)

[9] Bionatura 15(1) pp 49 – 53

[10] Hairiah K, Sugiarto C, Utami S.R, Purnomosidhi P and Roshetko J M 2014 Diagnosis faktor penghambat pertumbuhan akar sengon (Paraserianthes falcataria L. Nielsen) pada ultisol di Lampung Utara Agrivita 26(1) pp 89-97

[11] Ainingsih N, Triastinurmiatiningsih and Bramasto Y 2016 Respons of the red and white jabon seed from many sources of Indonesian to dry and wet treatments Available on page ejournal.unpak.ac.id

[12] Sudomo, A. 2007. The influence of sand clay on the growth of sengon and patchouli on agroforestry system. For Plant Breed 1(2) pp 1-8 [Indonesian]

[13] Wahyudi and Panjaitan S 2013 The comparation of agroforestry system intensive monoculture and conventional monoculture in the development of sengon plantation forest Prosiding Seminar Nasional Agroforestry 2013 pp 165-171 [Indonesian]

[14] Sudarmadji, T and Hartati W. 2016. The Process of rehabilitation of mined forest lands toward degraded forest ecosystem recovery in Kalimantan Indonesia Biodiversitas 17(1)

[15] Sarminah S, Karyati, Karmini, Simbolon J and Tambunan E 2018 Rehabilitation and Soil conservation of degraded land using sengon (Falcataria maluccana) and peanut (Arachis hypogeae) agroforestry system Biodiversitas 19(1) pp 222-228

[16] Karyati, Sarminah S, Karmini, Simangunsong G and Tamba J 2018 The mixed cropping of Anthocephalus cadamba and Glycine max for rehabilitating sloping lands Biodiversitas 19(6) pp 2088-2095

[17] Regulation of Directorate General of Watershed Management and Social Forestry Republic of Indonesia number: P.4/V-SET/2013 [Indonesian]

[18] KRUS 2014 Annual report of Mulawarman University Botanical Garden Samarinda (KRUS) [Indonesian]

[19] Hardjoamidjojo S dan Sukartaatmadja S 2008 Teknik Pengawetan Tanah dan Air Graha Ilmu Bogor

[20] Arsyad S 2010 Konservasi Tanah dan Air IPB Press Bogor

[21] Buckman H O and Brady N C 1982 Soil Science Penerbit Bhratharakarya Aksara Jakarta [Indonesian]

[22] Hammer W I 1981 Second soil conservation consultant report AGOF/INS/78/006 Tech

[23] Note 10Centre for Soil Research Bogor Indonesia