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# Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system

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**Abstract.** *Sarminah S, Karyati, Karmini, Simbolon J, Tambunan E. 2018. Rehabilitation and soil conservation of degraded land using sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) agroforestry system. Biodiversitas 19: 222-228.* Rehabilitation and soil conservation effort on degraded lands is not always a success. Multiple factors, such as the field' biogeophysical conditions and the choice of suitable plant species determine the effectivity of the rehabilitation program. Our research aimed to implement agroforestry system of sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) on degraded land at different soil slopes (a steep and a slightly steep slope gradient) and to analyze the effect of the system on silvicultural and hydro-orological aspects of the degraded land. The silvicultural parameters examined in this study were the ground coverage of peanut growth and the stem diameter and height of sengon trees. Meanwhile, the hydro-orological parameters included potential erosion rate, erosion hazard index, and erosion hazard level. Our study revealed that on the land with the slightly steep slope (15-25%), the survival rate of sengon reached 90%, the ground coverage of the peanuts was 70-80%, the diameter and height increment of sengon trees reached 2.47 cm/year and 17.58 cm/year, respectively. Meanwhile, the potential erosion rate was 20.05 ton/ha/year, with an erosion hazard index of 0.80 (low) and a low hazard level. In the steeper ground (25-40%), the survival rate of sengon reached 90%, the peanut coverage was 50-60% and the diameter and height increment of the sengon were 2.37 cm/year and 16.41 cm/year, respectively. In the steep ground, potential erosion rate was 45.50 ton/ha/year, with an erosion hazard index of 3.25 (moderate) and a low hazard level. We concluded that the rehabilitation and soil conservation using sengon-peanut agroforestry system effectively suppressed erosion rate to a low erosion hazard.

**Keywords**: Erosion, slope, soil conservation, growth, land rehabilitation

## INTRODUCTION

Critical lands suffer from low productivity and are gradually degraded. Forest damage affects the forest structure and composition, which in turn lead to the formation of unproductive lands. These degraded lands become increasingly critical due to erosion triggered by careless and irresponsible human activities. Exploitation of natural resources beyond the environment carrying capacity and human pressure to the land without proper soil and water conservation measures will result in an ecological imbalance as represented by the increasing number of degraded land. Pathak et al. (2017) stated that annual controlled fires replenish the soil nutrients and promote higher production of biomass in degraded lands infested with cogon grass weed. Nugroho (2000) reported that in 1974, the total area of degraded land in Indonesia reached 10,751,000 ha and increased to 23,725,552 ha in 1998. Efforts to minimalize the rate of land degradation can be done structurally (reforestation, afforestation, terracing, check dam construction, etc.) and non-structurally by involving the participation of the community, improving the income of the people, counseling, etc. (Nugroho 2000).

According to Daswir (2010), one way to suppress land degradation is by implementing conservation agricultural system. The system involves farmers in the soil and water conservation endeavors. Conservation agriculture practices can prevent further land degradation and the loss of productive soil, suppress erosion, and increase the farming productivity and the income of the farmer (Syam 2003). Syam (2003) added that soil conservation, in particular, must take into account three critical factors, rainfall intensity, land condition (slope, column thickness, and soil properties), and farmer's situation (cost, time, and labor).

Rehabilitation of degraded lands can be done by using vegetative conservation, mechanical conservation or combination of vegetative and mechanical conservation approaches. Vegetative conservation is a widely used and recommended soil and water conservation technique due to its convenient nature. Matching plant species with the land site is crucial in implementing vegetative conservation. Juhaeti et al. (2005) stated that a plant species that can grow well in a degraded land indicates that that species has a right tolerance toward such type of marginal land. Daswir (2010) suggested alley cropping as an economical and straightforward conservation method for farmers. Alley cropping is planting annual crops in between rows of trees or hedges. Alley cropping provides microclimate benefit to the annual crop. In general, leguminous vegetables, annual crops, and forest crops can grow well in an area with 600-

2500 mm/year rainfall, 18-35°C temperature, and 50-85% relative humidity (Karyati 2003, 2008).

Sarminah (2014) suggested that the choice of plant species for land rehabilitation and water and soil conservation program must be carefully taken into consideration. In general, ground cover plants are vine-type legumes that are planted in between the annual crops, grown alternatively with the annual crops, or raised as pioneer crops in degraded land rehabilitation (Idjudin 2011). The merit of sengon (*Falcataria moluccana*) as forest tree species for agroforestry has been reported by Sudomo (2007) and Wahyudi and Panjaitan (2013). In addition to the suitable plant species, the success of land rehabilitation project is determined by the proper combination of the plants constituting the agroforestry system. The combination must not only satisfy the biogeophysical condition of the land but also be compatible with the social, economic, and cultural aspect of the local community. Karmini et al. (2017) reported that sengon-peanut-based agroforestry system in East Kalimantan made a profit of Rp 3,015,000.00/ha/season (226.96 USD/ha/season).

As an alternative land rehabilitation policy, agroforestry system is viable to be applied on a degraded land. Agroforestry offers generous benefits, it is a relatively simple technology with widely available resources; plants are quick and easy to grow, and it has a low cost even upon large-scale application on degraded land. Thus, this study aims to implement an agroforestry system of sengon and peanut on degraded land with different soil slopes (a steep and a slightly steep slope gradient) and to analyze the effect of the system on silvicultural and hydro-orological aspects of that land.

## MATERIALS AND METHODS

### Study location

This research was conducted on a degraded land located in the Education Forest of Forestry Faculty, Mulawarman University, Lempake Sub-district, Samarinda City, East Kalimantan Province, Indonesia. The study took place for six months from January to June 2017. The experimental forest had a total area of 300 ha and was geographically located at 0°25'10"-0°25'24" South latitude and 117°14'00"-117°14'14" East longitude, in between The Samarinda-Bontang Highways Kilometers 10 and 13. The experimental forest is administratively situated in Tanah Merah Village, North Samarinda Sub-district, Samarinda City, East Kalimantan Province. The forest is bordered by Sempaja Village to the north, Mugirejo Village to the south, Lempake Village to the west, and Sungai Siring Village to the east (KRUS 2013; KRUS 2014). The study location map is shown in Figure 1.

According to Meteorological, Climatological, and Geophysical Agency of Indonesia (BMKG), during the last seven years, the research location encountered 211.5 mm monthly rainfall, 27.4°C average temperature, 82.2% relative humidity, and 41.8 hours average irradiation (Karyati 2015). The daily temperature inside the forest ranged 23.7°C-30.9°C, while the outside temperature was 25.9°C-28.8°C. Daily relative humidity inside and outside the forest were 81.4%-99.3% and 76.0%-90.0%, respectively. The daily average light intensity ranged from 1.08 µmol to 18.41 µmol (Karyati and Ardianto 2016). According to Schimdt-Ferguson (1951) system, the climate of Samarinda City was classified as type A climate, with a quotient (Q) of 0.048, which means that the city is highly humid with a tropical rainforest vegetation (Karyati et al. 2016).

The experimental forest is a lowland tropical rainforest located about 50 m above sea level. The forest was initially a natural forest composed predominantly with Dipterocarpaceae. After fires in 1983, 1993, and 1998, the forest stabilized and became an early secondary forest. Now, the forest has been in a late secondary forest stage and on its way toward climax state. Some of the plant species predominantly found in the forest were ulin (*Eusideroxylon zwageri*), puspa (*Schima wallichii*), medang (*Litsea* spp.), meranti (*Shorea* spp.), etc. Meanwhile, animals found in the forest were invertebrates such as protozoa, annelids, mollusks, crustacean, insects, arachnoids; and vertebrates including fish, frogs, birds, reptiles, and mammals (KRUS 2013; KRUS 2014).

### Instruments and materials

Tools and instruments that used in this study included measuring tape, clinometer, compass, diameter measuring tape (phi-band), microcaliper, machete, hoe, sickle, galvanized zinc roof sheets, PVC pipe, drum, ruler, soil sampling ring, ombrometer, graduated cylinder, filter paper, bucket, hand sprayer, camera, and stationery.

### Experimental procedures

10 m x 10 m experimental plots were prepared for two different slope classes in the experimental forest area, a slightly steep slope (15-25%, henceforth called Plot 1), and a steep slope (25-40%, henceforth called Plot 2). Sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea* L.) were grown on both plots. Sengon trees were planted with a spacing of 3 m × 3 m. Peanut, as the groundcover legumes were planted in between the sengon trees. 10 m × 3 m erosion measurement plots, were arranged on the two experimental plots. Hydro-orological parameters measurements were conducted at 35 times rain events. Plant maintenance was performed accordingly, including watering, weeding, fertilizer application, and pest and plant diseases control. Harvesting was done on the groundcover peanut produce and not on the sengon trees.

### Analysis of soil properties

For soil profile description, a soil pit with the depth of 1.5 meter was dug at the center of study plot. Soil profile descriptions were conducted adopting the standard procedures by International Soil Science Society (ISSS) (NRCS 2002). The soil profile description was conducted by observing the characteristics of the soils moving towards the bottom of profile. Some of the characteristics were distinguished such as depth and field texture.

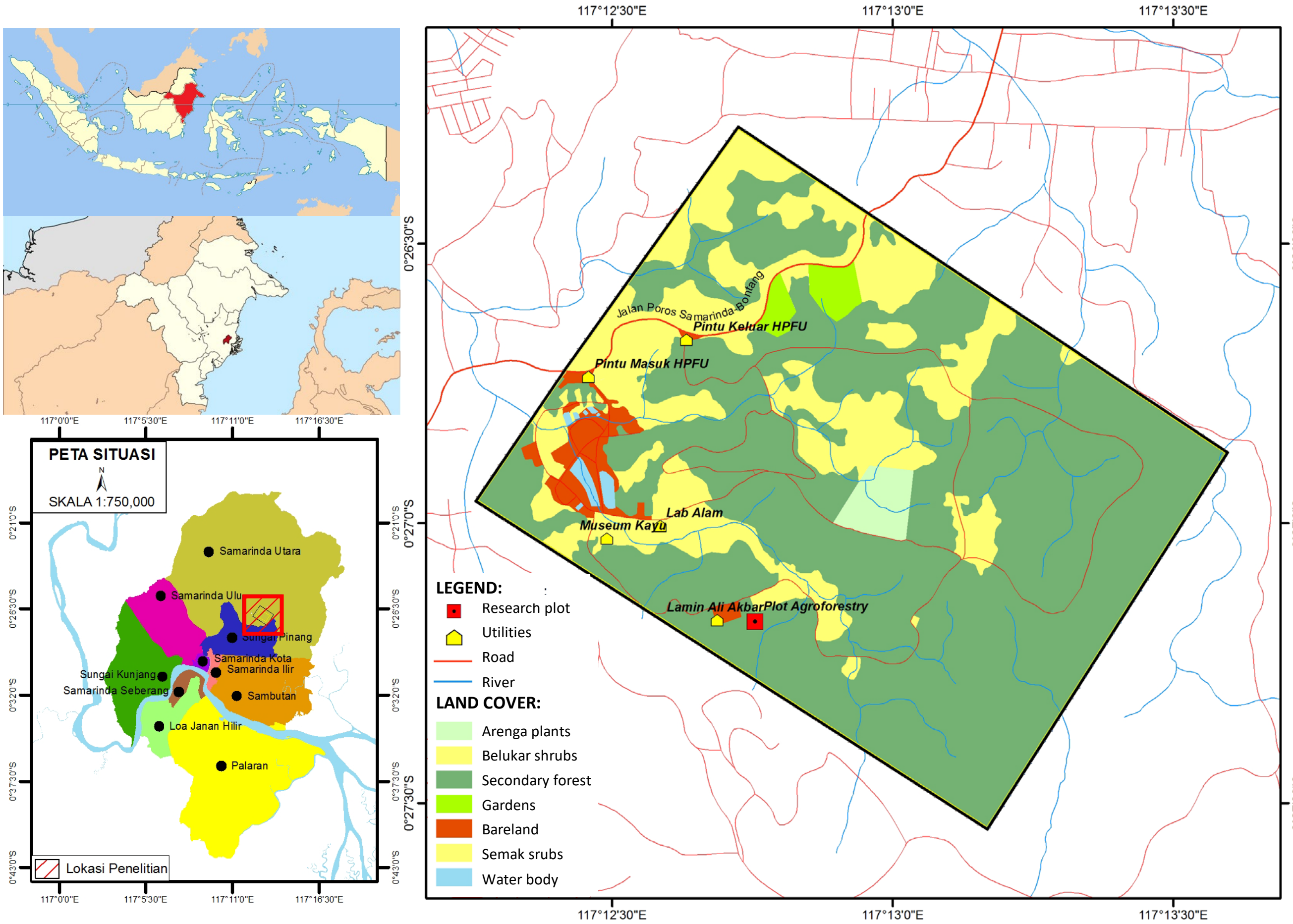


**Figure 1.** Study location in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, Indonesia

The analysis of soil physicochemical properties (pH ($H_2O$), pH (KCl), C organic, total N, P, K, and texture) were conducted in Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University, Samarinda, Indonesia. Soil pH was determined in distilled water and 1 N KCl in a soil to solution ratio of 1:2.5 by the glass electrode method. The total nitrogen (total N) was analyzed using Kjeldahl method. Soil P and K were analyzed using Bray 1 method.

### Data analysis

Plant growth observation and measurement were done at the end of every month for four months. The observation was carried out on both sengon and peanut plants. In addition, sengon's survival rate, peanut's ground coverage, and sengon tree height and diameter were measured as well. Hydro-orological parameters measured in this study included surface runoff, potential soil erosion rate, erosion hazard index, and erosion hazard level (Hammer 1981). Classification of erosion hazard index and erosion hazard level are presented in Table 1 and Table 2, respectively. Formula to determine erosion hazard index is as follows (Hammer 1981):

Erosion hazard index = Potential erosion rate (ton/ha/year) / Tolerable erosion rate (ton/ha/year)

**Table 1**. Erosion hazard index categories (Hammer 1981)

| Erosion hazard index | Category |
|---|---|
| < 1.00 | Low |
| 1,01-4,00 | Moderate |
| 4,01-10,00 | High |
| > 10,01 | Very high |

**Table 2**. Erosion hazard level classification

| Soil column (cm) | Erosion rate (ton/ha/year) | | | | |
|---|---|---|---|---|---|
| | <15 | 15-<60 | 60-<180 | 180-480 | >480 |
| Deep (>90) | Very low | Low | Moderate | High | Very high |
| Intermediate (60-90) | Low | Moderate | High | Very high | Very high |
| Shallow (30-<60) | Moderate | High | Very high | Very high | Very high |
| Very shallow (<30) | High | Very high | Very high | Very high | Very high |

Source: Regulation of Directorate General of Watershed Management and Social Forestry, Ministry of Forestry Republic of Indonesia (2013)

## RESULTS AND DISCUSSION

### Silviculture aspect

In general, sengon and peanut grew well and healthy, as indicated by the formation of dense shoots and leaves. During the first two weeks, the peanut growth had yet to grow evenly both in Plot 1 and Plot 2. The qualitative evaluation of sengon and peanut growth are summarized in Table 3.

Qualitative evaluation was conducted based on visual observation of sengon and peanut plants in the field (Table 3). A well-grown plant was described as a plant with a vigorous appearance, fresh green leaves, normal stem growth, densely grown flowers, and a canopy coverage as high as 80%. Fairly grown plant was described as a plant with relatively fair body vigor, mostly green leaves with very few yellow leaves, a stem size ranged from small to big, relatively less dense flowers, and a canopy coverage of less than 60%. Observation at the end of study revealed that sengon trees in Plot 1 and Plot 2 exhibited a high survival rate of about 90% (Figure 2). This result indicates that the sengon trees can grow well in such a critical land. Ground coverage of peanut plants grown in Plot 1 and Plot 2 were 70-80% and 50-60%, respectively (Figure 3).

Table 4 and 5 show the monthly diameter and the height increments of sengon trees, respectively, that were monitored for 4 months. Judging from these results, sengon trees on the slightly steep slope (Plot 1) show a better growth performance in term of diameter and height increment compared with sengon trees on the steeper slope (Plot 2). The mean stem diameter increment of sengon located on the less steep and on the steep slope is 2.47 cm/year and 2.37 cm/year, respectively. Meanwhile, the height increments of sengon trees on the slightly steep and the steep slopes are 17.58 cm/year and 16.41 cm/year, respectively. Sengon diameter increment obtained in our agroforestry system is lower than those of the previous study by Swestiani and Purwaningsih (2013). They reported that the mean annual diameter increment of sengon grown on an agroforestry system and a monoculture system were 5.25 cm/year and 3.20 cm/year respectively. Similarly, a study by Wahyudi and Panjaitan (2013) reported that sengon grown on an agroforestry system showed the highest diameter increment (3.45 cm/year) compared with that of the sengon cultivated in an intensive monoculture (3.21 cm/year) and a conventional monoculture system (1.99 cm/year). Interestingly, the diameter increments of sengon obtained in this study were higher than that of predominant trees grown in a secondary tropical forest (0.75-0.86 cm/year) (Karyati et al. 2017). In a study on agroforestry system cultivating a combination of sengon and nilam, Sudomo (2007) reported that 18-month-old sengon exhibited a stem diameter and a height of 6.85 cm and 5.59 cm, respectively. Whereas, at 24 months of age, the sengon reached 9.48 cm in diameter and 7.28 m in height (Sudomo 2007).

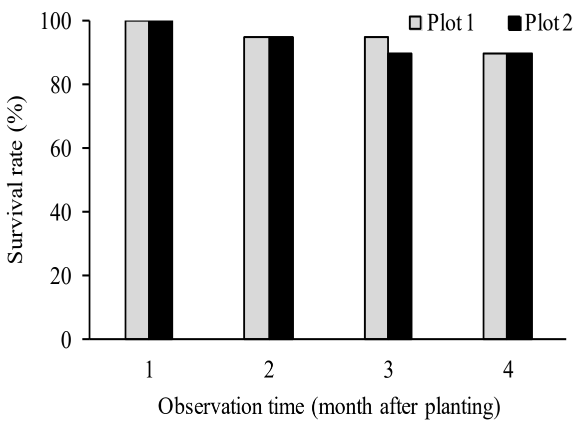


**Figure 2.** Survival rate of sengon in agroforestry system on the two different slopes

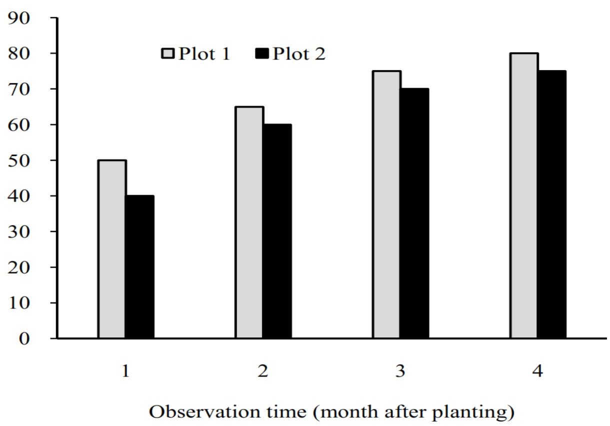


**Figure 3.** Ground coverage of peanut plants in agroforestry system on the two different slopes

**Table 3**. Qualitative evaluation of sengon dan peanut growth on the two different slope conditions

| Plant species | Plot 1 | | | | Plot 2 | | | |
|---|---|---|---|---|---|---|---|---|
| | Month | | | | Month | | | |
| | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| Sengon | Fair | Good | Good | Good | Fair | Fair | Good | Good |
| Peanut | Fair | Good | Good | Good | Fair | Fair | Good | Good |

Note: Plot 1 = experimental plot with 15-25% slope; Plot 2 = experimental plot with 25-40% slope located in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, Indonesia.

**Table 4.** Sengon stem diameter increment (mm) on the two different slopes.

| Tree number | Plot 1 | | | | | Plot 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $D_0$ | $d_1$ | $d_2$ | $d_3$ | $d_4$ | $D_0$ | $d_1$ | $d_2$ | $d_3$ | $d_4$ |
| 1 | 1.32 | 3.26 | 4.88 | 6.80 | 8.05 | 1.57 | 2.08 | 3.03 | 5.31 | 7.55 |
| 2 | 1.42 | 2.50 | 4.91 | 7.10 | 8.10 | 1.02 | 2.15 | 3.74 | 6.46 | 8.20 |
| 3 | 1.12 | 3.68 | 4.82 | 6.50 | 7.95 | 1.17 | 2.31 | 3.09 | 5.53 | 7.35 |
| 4 | 1.68 | 3.04 | 4.18 | 6.31 | 7.85 | 1.87 | 2.34 | 4.15 | 5.55 | 7.70 |
| 5 | 1.59 | 3.25 | 4.47 | 6.97 | 8.10 | 1.66 | 2.71 | 4.43 | 6.88 | 8.05 |
| 6 | 1.39 | 3.18 | 4.84 | 6.50 | 8.20 | 1.46 | 3.07 | 4.02 | 5.59 | 7.65 |
| 7 | 1.20 | 3.08 | 4.36 | 6.94 | 8.05 | 1.13 | 3.23 | 4.12 | 5.27 | 8.10 |
| 8 | 2.81 | 2.49 | 3.93 | 6.81 | 8.00 | 1.10 | 3.43 | 4.74 | 5.00 | 7.85 |
| 9 | 2.11 | 3.01 | 4.26 | 7.00 | 8.70 | 1.13 | 3.70 | 4.74 | 5.62 | 7.60 |
| 10 | 1.02 | 2.69 | 4.16 | 7.20 | 9.20 | 1.19 | 3.74 | 4.44 | 5.28 | 7.40 |
| 11 | 1.66 | 2.32 | 3.68 | 6.24 | 8.40 | 1.12 | 3.66 | 4.87 | 5.75 | 8.40 |
| 12 | 1.79 | 2.44 | 3.97 | 6.91 | 8.80 | 1.53 | 3.07 | 4.47 | 5.49 | 8.30 |
| 13 | 1.59 | 2.38 | 3.89 | 6.06 | 8.50 | 1.00 | 2.84 | 3.12 | 5.05 | 7.90 |
| 14 | 1.63 | 2.79 | 4.00 | 6.67 | 8.00 | 1.88 | 2.16 | 4.14 | 4.78 | 7.95 |
| 15 | 1.52 | 2.61 | 3.90 | 6.57 | 7.90 | 1.68 | 3.93 | 4.53 | 6.17 | 8.20 |
| 16 | 1.02 | 2.47 | 3.87 | 6.98 | 8.20 | 1.39 | 3.65 | 4.10 | 6.13 | 8.20 |
| Mean | 1.55 | 2.82 | 4.26 | 6.72 | 8.25 | 1.37 | 3.00 | 4.11 | 5.62 | 7.90 |
| SD | 0.44 | 0.40 | 0.41 | 0.33 | 0.38 | 0.30 | 0.65 | 0.59 | 0.56 | 0.33 |
| Annual diameter increment | 24.7 mm/year =2.47 cm/year | | | | | Annual diameter increment | 23.7 mm/year=2.37 cm/year | | | |

Note: Plot 1 = experimental plot located on 15-25% slope; Plot 2 = experimental plot located on 25-40% slope located in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, Indonesia; $D_0$ = initial stem diameter (diameter measured in the beginning of experiment); $d_1$,$d_2$, $d_3$, $d_4$ = diameter increments in the end of first, second, third, and fourth month after planting, respectively; SD=Standard Deviation

**Table 5**. Sengon height increment (cm) on the two different slopes

| Tree number | Plot 1 | | | | | Plot 2 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $H_0$ | $h_1$ | $h_2$ | $h_3$ | $h_4$ | $H_0$ | $h_1$ | $h_2$ | $h_3$ | $h_4$ |
| 1 | 54 | 25 | 33 | 49 | 58 | 58 | 24 | 34 | 44 | 54 |
| 2 | 54 | 26 | 35 | 52 | 61 | 60 | 27 | 37 | 47 | 57 |
| 3 | 53 | 27 | 32 | 48 | 58 | 56 | 23 | 33 | 43 | 54 |
| 4 | 59 | 29 | 35 | 47 | 58 | 56 | 24 | 34 | 44 | 54 |
| 5 | 57 | 27 | 35 | 47 | 57 | 55 | 23 | 33 | 43 | 53 |
| 6 | 57 | 28 | 36 | 48 | 59 | 57 | 25 | 35 | 45 | 55 |
| 7 | 58 | 29 | 39 | 50 | 61 | 56 | 25 | 35 | 45 | 56 |
| 8 | 59 | 28 | 35 | 49 | 58 | 55 | 24 | 34 | 44 | 54 |
| 9 | 61 | 31 | 43 | 54 | 60 | 57 | 26 | 36 | 46 | 56 |
| 10 | 56 | 29 | 38 | 49 | 56 | 56 | 23 | 33 | 43 | 53 |
| 11 | 55 | 27 | 37 | 43 | 57 | 54 | 22 | 32 | 42 | 52 |
| 12 | 56 | 29 | 32 | 47 | 60 | 55 | 25 | 36 | 46 | 57 |
| 13 | 57 | 28 | 33 | 49 | 60 | 56 | 26 | 36 | 46 | 56 |
| 14 | 54 | 25 | 36 | 48 | 58 | 55 | 24 | 34 | 44 | 54 |
| 15 | 60 | 33 | 42 | 50 | 57 | 54 | 22 | 32 | 42 | 53 |
| 16 | 60 | 34 | 46 | 51 | 60 | 59 | 27 | 36 | 46 | 57 |
| Mean | 57 | 28.44 | 36.69 | 48.81 | 58.60 | 56 | 24.38 | 34.38 | 44.38 | 54.70 |
| SD | 2.47 | 2.53 | 4.05 | 2.46 | 1.54 | 1.68 | 1.59 | 1.54 | 1.54 | 1.62 |
| Annual height increment | 175.8 mm/year=17.58 cm/year | | | | | Annual height increment | 164.1 mm/year=16.41 cm/year | | | |

Note: Plot 1 = experimental plot with 15-25% slope; Plot 2 = experimental plot with 25-40% slope located in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, Indonesia; $H_0$ = initial tree height (diameter measured in the beginning of experiment); $h_1$,$h_2$, $h_3$, $h_4$ = height increments in the end of first, second, third, and fourth month after planting, respectively; SD=Standard Deviation

Our data indicated that there were increases in diameter and height increments of sengon from month to month. These increases are presumably due to: (i) additional supply of organic matters contributed by the falling leaves of the peanut plants grown in between the sengon trees, (ii) the effect of NPK fertilizer application that served to fulfill the nutrient requirement of the plants for better growth quality and production, and (iii) the inherent fast-growing nature of the sengon trees. NPK fertilizer application in particular adequately supplies nitrogen for vigorous sengon growth. In addition, the fertilizers will improve soil structure by providing space for gas and water.

Sengon trees grown on the steep slope (Plot 2) show lower diameter and height increments compared with the trees on the slightly steep slope (Plot 1) (Table 2 and 3). This result indicates that slope gradient affects plant growth parameter, in particular, stem diameter and plant height. Kartasapoetra et al. (2000) stated that slope gradient determines soil fertility of a land. A land with relatively steeper slope is highly prone to soil erosion and nutrient leaching compared with a land with a less steep slope. The effect of slope steepness is also evident in the growth of the groundcover crop, the peanut plant. Ground coverage of the peanuts on the steep plot was lower than that of the peanuts on the slightly steep ground (Figure 2). The peanut plants seem to indirectly affect on the diameter and height growth of the sengon trees. It is through the decomposition of fallen leaves contributed for an extra source of organic materials for the growth of the sengon trees. Indeed, our chemical analysis indicated that there was an increase in soil nutrient content (C organic, N total, P, and K) and a change in soil pH ($H_2O$) from 4.12 at the beginning of the experiment to 4.93 at the end of the study as shown in Table 6.

**Hydro-orological aspect**

In this study, rainfall measurements were conducted 35 times when rain event occurred. Mean rainfall during the study was 17.41 mm/day. Table 7 shows the rainfall data, surface runoff volume, and eroded soil mass of the agroforestry system on the two different slopes. The surface runoff rate, potential erosion rate, erosion hazard index, and erosion hazard level is showed in Table 8.

Our results indicate that the steeper the slope, the higher the surface runoff volume and the erosion potential. In addition to slope gradient, the erosion rate is also determined by soil texture. Soil texture analysis indicates that the soil in this current study location is sandy loam, it is characterized by its fine texture as presented in Table 6. A finely textured soil has low water infiltration capacity. Thus, even a relatively low rainfall can generate a surface runoff on such a soil. Fine soil grains are difficult to form a stable soil structure because of the fragile cohesion between their particles, thereby highly susceptible to erosion (A'Yunin 2008).

Erosion hazard evaluation is an assessment and prediction about the scale of soil erosion and its potential danger to a particular plot of land. Erosion hazard level can indicate whether erosion is at a level that threatens or even endangers a land. We found that the potential erosion rate in Plot 1 was 20.05 ton/ha/year and in Plot 2 was 45.05 ton/ha/year. Therefore, the erosion hazard index of Plot 1 and Plot 2 were 0.80 (low) and 3.25 (moderate), respectively (Table 8). With a soil column deeper than 90 cm, the erosion rate of both Plot 1 and Plot 2 were in the range between 15-60 ton/ha/year, which are classified as low-hazard erosion according to classification system described in Table 2. This result suggests that the sengon-peanut agroforestry system is capable to suppress the erosion rate. Land rehabilitation and soil conservation by using sengon-peanut agroforestry system on different slope gradient show a positive impact on the land because the system can suppress the erosion rate up to a degree classified as low erosion hazard.

**Table 6**. The soil physicochemical properties in the study plot

| Soil chemical properties | At the beginning of study | At the end of study |
|---|---|---|
| pH ($H_2O$) | 4.12 | 4.93 |
| pH (KCl) | 3.37 | 4.26 |
| C organic (%) | 2.74 | 3.82 |
| N total (%) | 0.18 | 0.27 |
| $P_2O_5$ (ppm) | 19.59 | 23.51 |
| $K_2O$ (ppm) | 103.11 | 114.07 |
| Texture | Sandy Loam (SL) | Sandy Loam (SL) |

**Table 7.** Rainfall, surface runoff volume, and eroded soil mass of agroforestry system on two different slopes

| Rain event | Rainfall (mm) | Surface runoff (l) | | Eroded soil mass (g) | |
|---|---|---|---|---|---|
| | | Plot 1 | Plot 2 | Plot 1 | Plot 2 |
| 1 | 24.38 | 17.55 | 32.52 | 985.82 | 1943.54 |
| 2 | 5.97 | 19.58 | 28.15 | 220.32 | 236.19 |
| 3 | 14.43 | 11.13 | 28.23 | 137.98 | 245.69 |
| 4 | 55.23 | 20.47 | 32.56 | 2985.70 | 9368.87 |
| 5 | 12.69 | 19.93 | 38.15 | 327.34 | 648.06 |
| 6 | 42.30 | 19.08 | 38.15 | 2074.65 | 3121.26 |
| 7 | 26.37 | 19.08 | 39.68 | 840.85 | 1020.41 |
| 8 | 6.72 | 18.31 | 36.24 | 251.80 | 334.78 |
| 9 | 8.46 | 16.79 | 38.15 | 775.23 | 977.68 |
| 10 | 36.33 | 19.84 | 37.64 | 1139.95 | 1675.59 |
| 11 | 8.96 | 18.88 | 28.61 | 477.01 | 524.58 |
| 12 | 14.18 | 16.79 | 34.34 | 327.34 | 927.07 |
| 13 | 13.44 | 13.59 | 21.94 | 288.04 | 518.85 |
| 14 | 13.68 | 19.01 | 39.17 | 477.78 | 784.38 |
| 15 | 2.99 | 3.12 | 4.39 | 36.50 | 45.91 |
| 16 | 2.49 | 1.72 | 1.21 | 14.94 | 15.74 |
| 17 | 17.42 | 20.28 | 33.57 | 372.10 | 690.79 |
| 18 | 19.66 | 15.90 | 36.12 | 773.19 | 1186.24 |
| 19 | 29.86 | 23.14 | 35.61 | 912.57 | 1111.97 |
| 20 | 8.71 | 15.45 | 37.13 | 128.19 | 221.78 |
| 21 | 38.81 | 19.84 | 35.61 | 838.56 | 1633.88 |
| 22 | 7.71 | 16.02 | 30.20 | 167.67 | 340.18 |
| 23 | 17.17 | 18.88 | 37.64 | 935.84 | 1337.83 |
| 24 | 26.87 | 20.67 | 35.61 | 751.10 | 852.55 |
| 25 | 2.74 | 5.53 | 7.44 | 48.64 | 59.90 |
| 26 | 2.74 | 2.29 | 4.83 | 16.79 | 25.18 |
| 27 | 2.74 | 2.43 | 3.72 | 17.84 | 20.22 |
| 28 | 3.98 | 1.53 | 2.48 | 10.94 | 18.82 |
| 29 | 5.47 | 11.57 | 24.70 | 160.23 | 330.48 |
| 30 | 3.73 | 2.67 | 3.77 | 18.60 | 35.48 |
| 31 | 15.43 | 11.16 | 22.32 | 127.30 | 177.40 |
| 32 | 43.29 | 18.31 | 38.15 | 339.54 | 358.11 |
| 33 | 18.66 | 3.17 | 5.02 | 20.70 | 45.91 |
| 34 | 45.28 | 24.04 | 39.17 | 562.60 | 574.81 |
| 35 | 10.45 | 23.14 | 35.61 | 210.78 | 245.18 |
| Total | 609.34 | 510.90 | 947.83 | 17774.42 | 31655.32 |
| Mean | 17.41 | 14.60 | 27.08 | 507.84 | 904.44 |

Note: Plot 1 = experimental plot with 15-25% slope; Plot 2 = experimental plot with 25-40% slope located in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, Indonesia

**Table 8.** Surface runoff rate, potential erosion rate, erosion hazard index, and erosion hazard level of agroforestry system on two different slopes

| Slope gradient | Surface runoff rate ($m^3$/ha/year) | Potential erosion rate (ton/ha/year) | Tolerable erosion rate (ton/ha/year) | Erosion hazard index | Erosion hazard level |
|---|---|---|---|---|---|
| Plot 1 | 794.55 | 20.05 | 25 *) | 0.80 (Low) | Low |
| Plot 2 | 846.61 | 45.50 | 25 *) | 3.25 (Moderate) | Low |

Note: Plot 1 = experimental plot with 15-25% slope; Plot 2 = experimental plot with 25-40% slope located in the Education Forest of Forestry Faculty, Mulawarman University, Samarinda, Indonesia. *) Soil depth based on soil profile made at research site, i.e.,> 100 cm. In general, the tolerable erosion rate for hilly or sloping land is 25 ton/ha/year (Rahim 1995)

The vegetative conservation of a degraded land by using agroforestry system primarily consists of three essential benefits: (i) mitigation of surface runoff and erosion, (ii) suppression and reduction of raindrops impact on the soil surface, and (iii) recovery and improvement of degraded land into a productive land (Kartasapoetra et al. 2000). Our study shows that sengon-peanut agroforestry is suitable to be implemented for rehabilitation and soil conservation of degraded land with different slope conditions. We hope that the result of this research can be applied and become a reference for all the stakeholders, including private parties and the government, especially Ministry of Environment and Forestry and Ministry of Agriculture of the Republic of Indonesia.

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