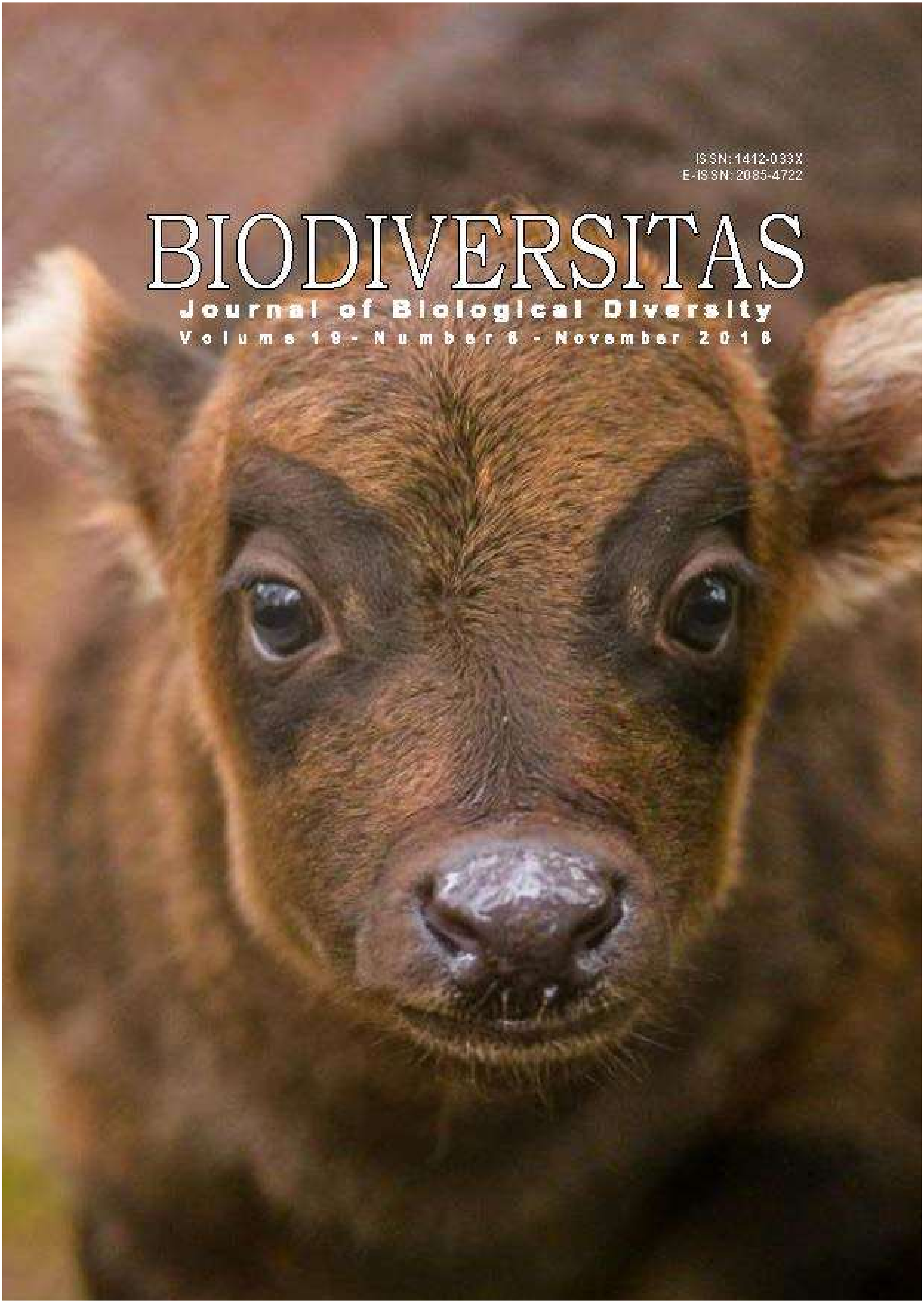

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The mixed cropping of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands

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Abstract. *Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The mixed cropping of* Anthocephalus cadamba *and* Glycine max *for rehabilitating sloping lands. Biodiversitas 19: 2088-2095.* Agroforestry system is one of the many alternatives to overcome problems concerning sloping lands. The objectives of this current study were to analyze the effect of agroforestry system in the form of mixed cropping of jabon tree (*Anthocephalus cadamba* Mig) and soybean (*Glycine max* Merr) on growth and hydro-orological aspects on sloping lands with different steepness (a slightly steep and a steep slope gradient). The growth parameters (survival rate, ground coverage, diameter increment, and height increment) and hydro-orological parameters (surface runoff, potential erosion, erosion hazard index, and erosion hazard level) were observed in this study. The findings showed that on the slightly steep slope (>15-25%) land, the survival rate of *A. cadamba* was 90%, the ground coverage of the *G. max* was 70-79%, the diameter and the height increments of *A. cadamba* trees were 1.8 cm year^{-1} and 13.8 cm year^{-1} respectively. Meanwhile, the potential erosion rate and the erosion hazard index were 32.13 ton ha^{-1} year^{-1} and 1.29, respectively. In the steeper slope (>25-45%), the survival rate of *A. cadamba* reached 90%, the *G. max* ground cover reached 60-69%, the diameter and height increments of the *A. cadamba* reached 1.5 cm year^{-1} and 12.0 cm year^{-1} respectively. Furthermore, in the steep slope, the potential erosion rate was 52.51 ton ha^{-1} year^{-1} and the erosion hazard index was 2.10. In addition, the potential erosion rate and the erosion hazard index in the control plot were higher than those in slightly steep slope. Therefore, it could be implied that the application of *A. cadamba* and *G. max* mixed cropping system could rehabilitate sloping lands.

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

INTRODUCTION

The total area of degraded lands in Indonesia is approximately 78 million ha, which consists of the slightly degraded area of 48 million ha, degraded area of 23 million ha, and highly degraded area of 7 million ha (ADB 2016). These degraded areas have existed due to biophysical, social, economic, and cultural factors (Matatula 2009). Therefore, the implementation of conservation agricultural system can be considered as an alternative to suppress land degradation (Daswir 2010). The agriculture practices have been proven capable of overcoming land degradation because these activities can reduce the loss of productive soil and suppress the erosion as well as increase the farming productivity and the farmer's income (Syam 2003). The combination of agricultural crops and forest trees in agroforestry system can optimize the use of land for agricultural production (Alao & Shuaibu 2013).

The cultivation technique in the marginal and sloping lands should focus on the integrated environmental factors (Budiastuti 2013). For instance, a plant species that has a suitable tolerance can grow well in a degraded land including some types of marginal land (Juhaeti et al. 2005). Furthermore, the soil conservation using a combination of upland rice with soybean sequence and *Mucuna bracteata* strip is found effective to reduce the runoff and to prevent the soil erosion and nutrient loss (Fuady et al. 2014). The choice of the right plant species is needed for the land rehabilitation and the water and soil conservation program (Sarminah 2014). Plants such as the legumes may serve as an alternative intercropping plant among annual crops that could be the pioneer crops planted in degraded land rehabilitation (Idjudin 2011). The various plant species of leguminous vegetables, annual crops, and forest crops can grow well in degraded lands as alternative plants in the agroforestry system. These plant species can adapt to climate elements with 600-2500 mm year^{-1} rainfall, 18-35°C temperature, and 50-85% relative humidity (Karyati 2008).

The rehabilitation and soil conservation using agroforestry system in the form of *sengon* (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) mixed cropping are effective in suppressing erosion rate to a low erosion hazard (Sarminah et al. 2018). The production of soybean (*Glycine max* Merr), which is a shade tolerant in the agroforestry system of *G. max* and *Paraserianthes falcataria* (4 years of age), has been found to be lower than *G. max* without shading (Hartoyo et al. 2014). The use of *G. max* as an intercropping plant in the agroforestry system of *jabon* (*Anthocephalus cadamba* Mig) and *G. max*, in the first year in the first cropping season would require a total cost of IDR 11,019,000.00 ha^{-1}cropping season (cp)$^{-1}$, and result in the total revenue of IDR 3,500,000.00 ha^{-1}cp^{-1} as well as the profit of IDR 7,519,000.00 ha^{-1}cp^{-1}, respectively (Karmini et al. 2017).

The agroforestry system as an alternative program may be implemented to rehabilitate sloping lands. In addition to providing economic benefit, the agricultural plant is expected to be able to cover the ground in the early years. Moreover, the forestry plant would be planted for soil and water conservation in long term program. Therefore, the objectives of this study were to implement the agroforestry system in the form of *A. cadamba* and *G. max* mixed cropping on sloping lands with different steepness (a slightly steep and a steep slope gradient) and to analyze the effect of that particular system on growth and hydro-orological aspects of the land.

MATERIALS AND METHODS

Study area

This study was carried out from March to October 2017 at a sloping land located in the Educational Forest of Mulawarman University Faculty of Forestry. The Educational Forest covers an area of 300 ha and is administratively situated in Tanah Merah Village, North Samarinda District, Samarinda Municipality, East Kalimantan Province (KRUS 2013; KRUS 2014). The geographic locations of this site is 0°25'10"-0°25'24" South Latitude and 117°14'00"-117°14'14" East Longitude. The study plot was located between the Samarinda-Bontang Highways between Kilometers 10 and 13. The map of the study area is shown in Figure 1.

During the last seven years, this study area has been observed to have an average of 211.5 mm monthly rainfall, 27.4°C of monthly temperature, 82.2% of monthly relative humidity, and 41.8 hours of average irradiation (Karyati 2015). The daily temperature and relative humidity inside the forest range from 23.7°C-30.9°C and 81.4%-99.3% respectively. While, outside the forest, the daily temperature is 25.9°C-28.8°C and the relative humidity is 76.0%-90.0%. The daily average light intensity ranges from 1.08 µmol to 18.41 µmol (Karyati & Ardianto 2016). Furthermore, the climate of Samarinda Municipality is categorized as type A climate based on Schmidt-Ferguson classification system (1951), with a quotient (Q) of 0.048, which is considered as a very humid area with a tropical rainforest vegetation (Karyati et al. 2016).

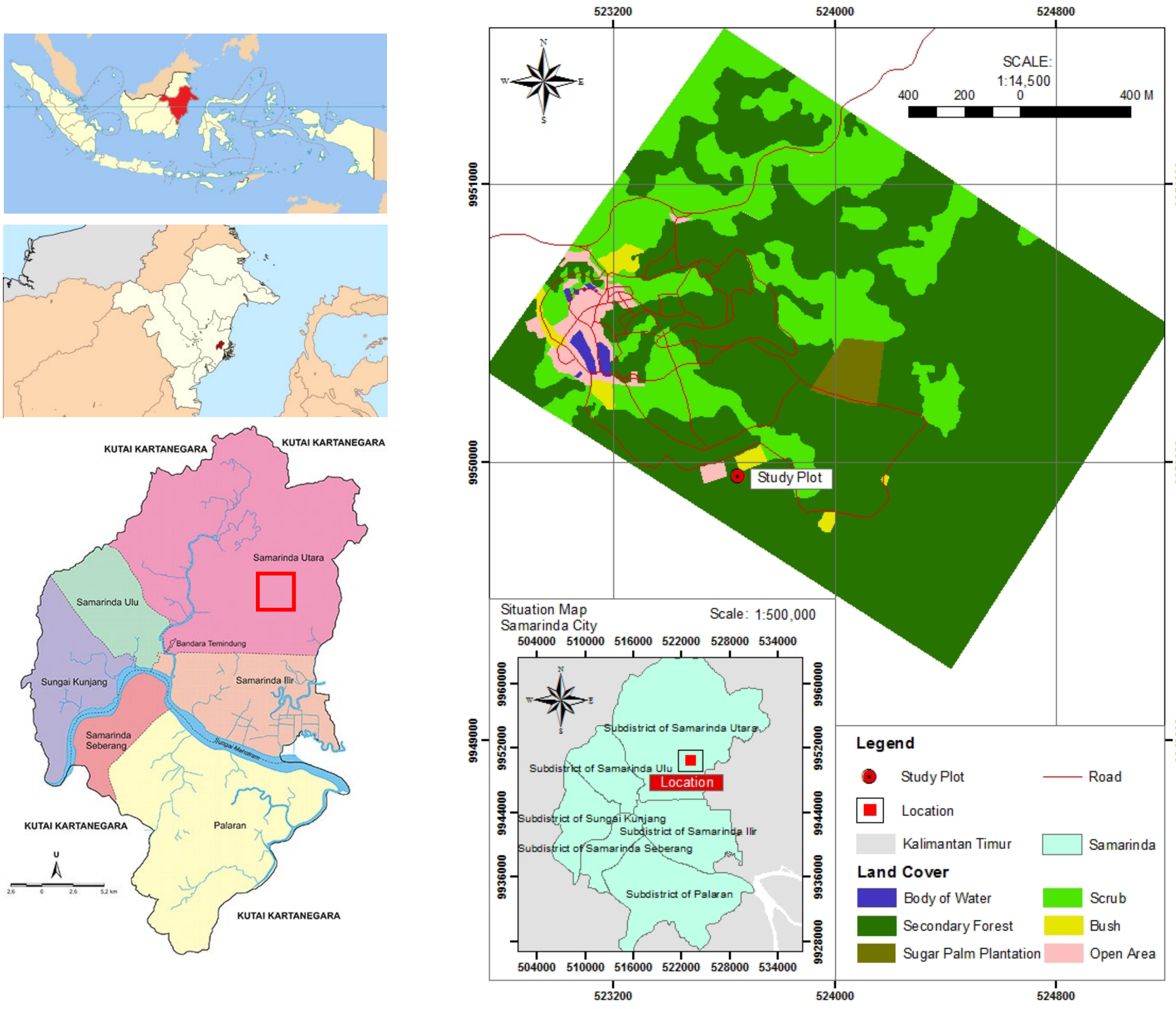

Figure 1. Location of study site in Education Forest of Forestry Faculty of Mulawarman University at East Kalimantan, Indonesia

The Mulawarman University Educational Forest is located about 50 m above sea level in a lowland tropical rainforest. The original vegetation was natural forest dominated by Dipterocarpaceae. After the forest fire incidents in 1983, 1993, and 1998, the forest land turned into early secondary forest. Nowadays, the forest is in the late secondary forest stage and is on its way towards the climax state. The plant species of *ulin* (*Eusideroxylon zwageri*), *puspa* (*Schima wallichii*), *medang* (*Litsea* spp.), and *meranti* (*Shorea* spp.) are predominantly found in the forest. In addition, animals of invertebrates (protozoa, annelids, mollusks, crustaceans, insects, and arachnoids) and vertebrates (fishes, frogs, birds, reptiles, and mammals) are also found in this area (KRUS 2013; KRUS 2014).

Procedures

Two experimental plots of 10 m × 10 m were established in two different slope classes in the Educational Forest area, namely a slightly steep slope (>15-25%) and a steep slope (>25-45%). *A. cadamba* and *G. max* were grown on both plots. *A. cadamba* trees was six months old. *A. cadamba* trees were planted with a spacing of 3 m × 3 m whereas *G. max* was planted between *A. cadamba* trees as the groundcover legumes. The plant growth parameters (healthy plant, survival rate, and ground coverage) were measured at the end of assessment. The criteria of these parameters were formulated based on Regulation of Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009. The diameter and height of *A. cadamba* were measured every month for 4 months.

Three erosion measurement plots of 10 m × 3 m were established on the two experimental plots and the control plot. The control plot was established on a moderate slope (>8-15%) without plantation. Furthermore, the hydro-orological parameters measurements were conducted for 35 times of rain events and the hydro-orological data were collected from May to September 2017 in the two different slopes as well as the control plot. Plant maintenance, such as watering, weeding, fertilization, and pest and plant diseases control, was performed regularly. The harvesting was only done for *G. max* whereas there was no harvesting done for the *A. cadamba* trees.

Data analyses

Soil properties

To obtain the soil profile description, a soil pit with the depth of 1.5 m was dug at the center of the study plot. Soil profile descriptions were done by adopting the standard procedures from the International Soil Science Society/ ISSS (NRCS 2002). Using these procedures, the characteristics of the soils from the topsoil through the bottom of profile were observed. Some of the characteristics, such as depth and field texture, were described. The analyses of soil physicochemical properties (pH (H_2O), pH (KCl), C organic, total N, P, K, and soil texture) were done at the Laboratory of Soil Science, Tropical Forest Research Center, Mulawarman University. The soil pH was determined in distilled water and 1 N KCl in a soil with a solution ratio of 1:2.5 using the glass electrode method. The total nitrogen (total N) was analyzed using Kjeldahl method whereas Soil P and K were analyzed using the Bray 1 method.

Erosion hazard index

The observation and measurement of growth parameters were done at the end of every month for four months. The observation was conducted for both *A. cadamba* and *G. max*. *A. cadamba*'s survival rate, *G. max*'s ground coverage, and the diameter and height of *A. cadamba* tree were observed as well. In addition, hydro-orological parameters of surface runoff, potential soil erosion rate, erosion hazard index, and erosion hazard level were also measured in this study (Hammer 1981). The classification of erosion hazard index and erosion hazard level can be seen from Tables 1 and 2, while the erosion hazard index was determined using the following equation (Hammer 1981):

$$\text{Erosion hazard index} = \frac{\text{Potential erosion rate (ton ha}^{-1}\text{ year}^{-1})}{\text{Tolerable erosion rate (ton ha}^{-1}\text{ year}^{-1})}$$

RESULTS AND DISCUSSION

Growth aspects

In general, *A. cadamba* and *G. max* grew well in different slope, as indicated by the parameters of plant performance. For instance, it was observed that during the first three weeks, the *G. max* almost grew evenly in the two experimental plots. The plant growth parameters of *A. cadamba* and *G. max* are summarized in Table 3.

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^{-1}year^{-1})				
	<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)

Table 3. The plant growth parameters of *A. cadamba* and *G. max* agroforestry system on the two different slope conditions.

Plant species	Slightly steep slope (>15-25%)				Steep slope (>25-45%)			
	Healthy plant (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})	Healthy plant (%)	Survival rate (%)	Ground coverage (%)	Yield (kg ha^{-1})
A. cadamba	90 (Very good)	90 (Very good)	-	-	90 (Very good)	90 (Very good)	-	-
G. max	80-89 (Good)	-	70-79 (Moderate)	525	70-79 (Moderate)	-	60-69 (Low)	485

Table 4. The soybean yield (ton ha^{-1}) of monoculture and agroforestry systems

Plantation system	*Glycine max* yield	Location	Researcher (year)
A 50-cm row width in full season soybean cropping A 30-cm row width in double-cropped soybean	4,142.5 kg ha^{-1} 3,241.5 kg ha^{-1}	Research Farm of Mustafa Kemal University, Hatay, Turkey	Caliskan et al. (2007)
Monoculture system of *G. max*	509-642 kg ha^{-1}	Saboba and Chereponi Districts, Northern Region of Ghana	Dogbe et al. (2013)
Monoculture system of *G. max*	1,000 kg ha^{-1}	Benin	Zoundji et al. (2015)
Agroforestry system of *Melia azedarach* and *G. max*		Experimental Garden Cikabayan, Kampus IPB, Dramaga, Bogor	Jauhari et al. (2016)
Variety of Argomulyo	720 kg ha^{-1}		
Variety of Anjasmoro	1,150 kg ha^{-1}		
Variety of Grobogan	640 kg ha^{-1}		
Variety of Wilis	560 kg ha^{-1}		
Non-agroforestry			
Variety of Argomulyo	620kg ha^{-1}		
Variety of Anjasmoro	900 kg ha^{-1}		
Variety of Grobogan	420 kg ha^{-1}		
Variety of Wilis	350 kg ha^{-1}		
Agroforestry system of *A. cadamba* and *G. max*	500 kg ha^{-1}	Samarinda, East Kalimantan, Indonesia	Karmini et al. (2017)
The average productivity of *G. max* in 2015	1604 kg ha^{-1} 1568 kg ha^{-1}	East Kalimantan Province Indonesia	Statistics of Indonesia (2017)
Agroforestry system of *A. cadamba* and *G. max*		Educational Forest of Forestry Faculty, Mulawarman University, Samarinda, East Kalimantan, Indonesia	This study
Slightly steep slope (>15-25%)	525 kg ha^{-1}		
Steep slope (>25-45%)	485 kg ha^{-1}		

Based on the observation, it was found that the number of healthy plants and the survival rate of *A. cadamba* on both plots could be classified into a “very good” (90%) category. In particular, the number of healthy plants and the ground coverage of *G. max* in the slightly steep slope was higher than those in steep slopes. Furthermore, the measurement for the yield also showed a similar trend of findings.

The average of *G. max* yield in the study site was similar to the findings of the previous studies in monoculture system (Dogbe et al. 2013) and agroforestry system (Jauhari et al. 2016; Karmini et al. 2017). This result was lower than those reported by Caliskan et al. (2007), Zoundji et al. (2015), as well as the average national yield (Statistics of Indonesia, 2017). Moreover, Jauhari et al. (2016) also reported that the yield of four *G. max* varieties planted in agroforestry system with *mindi* (*Melia azedarach* Linn) was higher than that in the non-agroforestry system. The *G. max* yields of monoculture and agroforestry system are presented in Table 4.

Tables 5 and 6 illustrate the monthly diameter and height increments of *A. cadamba* trees that were monitored for four months. *A. cadamba* trees on the slightly steep slope showed faster growth in terms of diameter and height increment than those on the steeper slope. The average stem diameter increments of *A. cadamba* were 1.8 cm year^{-1} and 1.5 cm year^{-1} on the less steep and steep slopes respectively. Meanwhile, the average height increments of *A. cadamba* trees on the slightly steep and the steep slopes were 13.8 cm year^{-1} and 12.0 cm year^{-1} respectively.

The average diameter increment of *A. cadamba* in *A. cadamba* and *G. max* agroforestry system was higher than reported by Krisnawati et al. (2011). Krisnawati et al. (2011) reported that the diameter and height of *A. cadamba* in Java were 1.2-11.6 cm year^{-1} and 0.8-7.9 m year^{-1}, while the growth of those in South Kalimantan was 1.2-4.8 cm year^{-1} and 0.8-3.7 m year^{-1} respectively. Similarly, the diameter increment of *A. cadamba* in this study was higher than the predominant trees in a secondary tropical forest, i.e., 0.75-0.86 cm year^{-1} (Karyati et al. 2017). The observation

Table 5. *Anthocephalus cadamba* stem diameter increments (mm) on the two different slopes

Tree no.	Slightly steep slope (>15-25%)					Steep slope (>25-45%)				
	D_0	d_1	d_2	d_3	d_4	D_0	d_1	d_2	d_3	d_4
1	1.02	2.26	3.38	4.58	6.10	1.02	2.26	3.15	4.10	4.80
2	1.02	2.50	3.41	4.30	5.50	1.02	2.50	3.34	4.10	4.90
3	1.02	2.68	3.52	4.70	6.20	1.03	2.28	3.12	3.90	4.50
4	1.08	2.04	3.18	4.51	5.85	1.08	2.04	3.00	4.03	4.70
5	1.09	2.25	3.47	4.57	5.90	1.06	2.25	3.36	4.15	5.00
6	1.09	2.18	3.14	4.40	5.60	1.09	2.18	3.05	4.10	4.80
7	1.00	2.08	3.16	4.54	5.76	1.00	2.08	3.00	3.90	4.60
8	1.01	2.49	3.43	4.61	6.30	1.01	2.49	3.03	4.15	5.05
9	1.11	2.01	3.26	4.50	5.76	1.09	2.01	3.15	4.20	5.15
10	1.02	2.19	3.16	4.30	5.65	1.02	2.19	3.16	4.20	5.10
11	1.06	2.32	3.38	4.44	5.75	1.06	2.32	3.25	4.24	5.10
12	1.09	2.24	3.42	4.71	6.40	1.09	2.24	3.20	4.10	5.00
13	1.09	2.38	3.39	4.56	5.84	1.10	2.18	3.00	4.00	4.70
14	1.03	2.29	3.20	4.37	5.60	1.02	2.29	3.10	4.15	4.80
15	1.02	2.21	3.30	4.47	5.74	1.02	2.21	3.10	4.00	4.60
16	1.02	2.17	3.27	4.28	5.58	1.04	2.17	3.00	4.00	4.70
Mean	1.05	2.27	3.32	4.49	5.85	1.05	2.23	3.13	4.08	4.84
SD	0.40	0.18	0.12	0.13	0.27	0.08	0.14	0.12	0.10	0.20
Annual diameter increment	17.5 mm $year^{-1}$ =1.8 cm $year^{-1}$					Annual diameter increment	14.5 mm $year^{-1}$ =1.5 cm $year^{-1}$			

Note: D_0 = initial stem diameter (diameter measurement at the beginning of experiment); d_1,d_2, d_3, d_4 = diameter increments at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation

Table 6. *Anthocephalus cadamba* height increments (cm) on the two different slopes

Tree no.	Slightly steep slope (>15-25%)					Steep slope (>25-45%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
1	52	20	28	36	44	50	17	26	30	37
2	52	21	28	35	43	51	19	26	31	39
3	50	17	23	31	40	50	18	25	31	38
4	55	23	32	40	48	54	22	29	35	43
5	54	22	30	38	46	53	20	27	33	42
6	54	21	30	39	45	52	19	25	32	40
7	55	22	31	39	45	54	22	28	34	42
8	55	21	31	40	46	53	21	28	35	41
9	56	23	33	41	49	55	23	30	35	42
10	53	21	32	40	47	52	21	29	34	40
11	52	20	28	35	43	52	20	26	32	39
12	53	20	29	36	45	54	22	28	34	41
13	54	22	31	38	47	51	20	27	32	39
14	52	20	27	35	44	54	23	29	35	41
15	56	24	33	41	50	53	21	28	33	40
16	56	24	32	42	50	52	18	24	30	37
Mean	54	21	30	38	46	53	20	27	33	40
SD	1.78	1.78	2.63	2.96	2.72	1.51	1.82	1.72	1.78	1.81
Annual height increment	138.0 mm $year^{-1}$ =13.8 cm $year^{-1}$					Annual height increment	120.0 mm $year^{-1}$ =12.0 cm $year^{-1}$			

Note: H_0 = initial tree height (height measurement at the beginning of experiment); h_1, h_2, h_3, h_4 = height increments at the end of the first, second, third, and fourth month after planting; SD=Standard Deviation.

Table 7. The soil physicochemical properties in the study plot.

Soil chemical properties	At the beginning of the study	At the end of the study
pH (H_2O)	4.09	4.83
pH (KCl)	3.35	4.16
C organic (%)	2.65	3.76
N total (%)	0.16	0.23
P_2O_5 (ppm)	19.47	23.10
K_2O (ppm)	100.15	113.56
Texture	Sandy Loam (SL)	Sandy Loam (SL)

data indicated that the diameter and height of *A. cadamba* increased from month to month. However, the diameter and height increments of *A. cadamba* trees on the steep slope were lower than those on the slightly steep slope. This result implied that slope gradient might affect plant growth parameter, especially the stem diameter and plant height. Furthermore, the soil erosion and nutrient leaching were relatively higher in the steeper slope than those in a less steep slope. Moreover, the ground coverage of the *G. max* on the steep plot was found to be lower than that on the slightly steep plot.

The *G. max* might indirectly influence the diameter and height growth of the *A. cadamba*. It is likely that the *G. max* supplied additional organic materials through the decomposition of leaf litter. This process contributed an extra source of organic materials for the growth of the *A. cadamba*. Interestingly, the chemical analyses indicated that soil nutrient contents (C organic, N total, P, and K) in the experimental plot increased during the study. Meanwhile, a change was observed in the soil pH (H_2O), from 4.12 (at the beginning of the experiment) to 4.93 (at the end of the study), as presented in Table 7.

Hydro-orological aspect

The surface runoff and eroded soil mass are influenced by many factors, such as the rainfall, soil erodibility, slope, vegetation, and management practice. During the study, the rainfalls were measured in the 35 occurrences of rain. Table 8 below presents the rainfall data and surface runoff volume of the agroforestry system on the two different slopes and the control plot, whereas the rainfall data and eroded soil mass of the agroforestry system on the two different slopes and control plot are presented in Table 9.

The result showed that in the event of high rainfall, the amount of surface runoff and eroded soil mass varied widely. The slope is not the only one factor that influences soil erosion. Generally, soil erosion was influenced by climate, soil, slope length and gradient, vegetation, and land management practices. However, in the steeper slope lands, the rainfall flowed to the lower area faster and more easily. It will lead to surface runoff and eroded soil mass as well erosion rate. The runoff rate increased from 20% to 90% by increasing slope and rain intensity (Chaplot and LeBissonnais 2000). In addition, the slope steepness and length influence the potential soil erosion. The erosion rate is also affected by soil properties, especially soil texture.

Table 8. Rainfall and surface runoff volume of agroforestry system on two different slopes and control plot

Rain event	Rainfall (mm)	Surface runoff (l/30 m²)		
		Control plot (>8-15%)	Slightly steep slope (>15-25%)	Steep slope (>25-45%)
1	24.38	36.67	22.32	33.48
2	5.97	28.18	24.13	29.25
3	14.43	26.22	21.94	30.14
4	55.23	11.13	28.93	37.39
5	12.69	12.71	25.18	32.81
6	42.30	15.30	31.00	33.06
7	26.37	14.70	31.41	32.65
8	6.72	41.20	32.65	34.72
9	8.46	25.71	23.08	29.17
10	36.33	15.82	24.13	29.73
11	8.96	5.12	19.17	27.47
12	14.18	38.40	28.52	40.34
13	13.44	30.10	19.73	21.08
14	13.68	24.34	28.49	37.39
15	2.99	10.29	12.46	17.80
16	2.49	24.35	4.32	5.47
17	17.42	39.40	27.85	31.67
18	19.66	25.10	21.68	31.47
19	29.86	28.20	32.94	36.50
20	8.71	8.50	22.89	27.98
21	38.81	41.70	29.76	33.89
22	7.71	28.62	23.84	27.98
23	17.17	24.70	28.61	31.28
24	26.87	4.00	30.90	36.48
25	2.74	8.50	8.98	10.43
26	2.74	4.60	8.90	10.17
27	2.74	11.20	5.56	6.36
28	3.98	14.50	3.10	3.77
29	5.47	18.95	18.57	20.35
30	3.73	3.50	5.40	6.28
31	15.43	20.10	15.09	17.98
32	43.29	14.20	25.94	31.28
33	18.66	40.10	21.75	24.04
34	45.28	37.85	30.71	38.72
35	10.45	25.20	26.86	33.06
Total	609.34	759.16	766.79	931.64
Mean	17.41	21.69	21.91	26.62

Table 9. Rainfall and eroded soil mass of agroforestry system on two different slopes and control plot

Rain event	Rainfall (mm)	Eroded soil mass (g/30 m²)		
		Control plot (>8-15%)	Slightly steep slope (>15-25%)	Steep slope (>25-45%)
1	24.38	1253.20	1102.69	2181.22
2	5.97	975.35	249.35	473.07
3	14.43	890.13	251.54	287.66
4	55.23	305.12	3172.64	8449.68
5	12.69	294.78	364.72	788.45
6	42.30	320.15	2344.25	3114.39
7	26.37	306.75	819.17	1400.90
8	6.72	4010.12	505.88	758.25
9	8.46	790.80	802.95	1057.04
10	36.33	360.24	1223.31	1895.34
11	8.96	200.15	456.10	669.55
12	14.18	3050.60	386.85	1340.88
13	13.44	1120.16	422.11	704.33
14	13.68	760.15	779.81	952.25
15	2.99	190.60	1443.44	493.10
16	2.49	800.10	76.56	412.16
17	17.42	2120.75	605.84	856.62
18	19.66	950.26	975.01	1350.04
19	29.86	1100.15	1110.96	1294.08
20	8.71	210.36	272.14	296.05
21	38.81	3810.65	949.77	1650.16
22	7.71	1320.10	237.81	248.81
23	17.17	1105.15	1112.48	1443.63
24	26.87	100.25	767.41	865.07
25	2.74	208.68	128.95	292.36
26	2.74	150.18	66.38	298.34
27	2.74	200.75	65.97	461.63
28	3.98	350.17	25.94	199.72
29	5.47	400.86	259.43	385.39
30	3.73	70.65	27.98	197.37
31	15.43	450.21	134.74	224.46
32	43.29	200.68	412.79	515.80
33	18.66	2985.10	154.51	358.62
34	45.28	1895.36	510.97	570.74
35	10.45	190.70	271.13	273.67
Total	609.34	33449.41	22491.58	36760.83
Mean	17.41	955.70	642.62	1050.31

The soil texture in the study site is sandy loam characterized by the fine texture as presented in Table 7. This soil has low water infiltration capacity. Additionally, low rainfall has caused a surface runoff in the surface soil. Fine soil grains do not form a stable soil structure easily because of the fragile cohesion between their particles, thereby highly susceptible to erosion (A'Yunin 2008).

The evaluation of erosion hazard is an assessment and prediction on the scale of soil erosion and its potential danger on a particular plot of land. Therefore, the erosion hazard level can be used as an indicator of whether the erosion is at a threatening level or is hazardous for a land. For sloping lands, the tolerable soil loss is 25 ton $ha^{-1}year^{-1}$ at a soil depth of more than 100 cm (Rahim 1995). The potential erosion rates in slightly steep slope and steep slope plots in this study were 32.13 ton $ha^{-1}year^{-1}$ and 52.51 ton $ha^{-1}year^{-1}$ respectively. Moreover, the erosion hazard index of 1.29 (low) and 2.10 (moderate) were observed in slightly steep slope and steep slope plots.

As the soil depth in the plot was more than 90 cm and the erosion rate of both slightly steep slope and steep slope plots were in the range between 15 ton $ha^{-1}year^{-1}$ and 60 ton $ha^{-1}year^{-1}$, the erosion hazard level of the study plots would be classified as the low erosion hazard according to classification system as described previously in Table 2. This result indicated that the agroforestry system of *A. cadamba*-*G.max* would be able to suppress the potential erosion rate. The implementation of *A. cadamba*-*G.max* agroforestry system could reduce the erosion rate to a degree classified as the low erosion hazard. The surface runoff rate, potential erosion rate, erosion hazard index, and erosion hazard level found in this study are shown in Table 10. The soil erosion rate of agroforestry system of *A. cadamba* and *G. max* on different slope lands in the study

Table 10. The hydro-orological parameters in the study site.

Planting system	Slope gradient	Surface runoff rate (m^3 ha^{-1} $year^{-1}$)	Potential erosion rate (ton ha^{-1} $year^{-1}$)	Tolerable erosion rate (ton $ha^{-1}year^{-1}$)	Erosion hazard index	Erosion hazard level
No plantation	>8-15%[1)]	1012.21	45.53	25[1)]	1.82 (Moderate)	Low
A.cadamba-G. max	>15-25%	1095.43	32.13	25[1)]	1.29 (Low)	Low
A.cadamba-G. max	>25-45%	1330.89	52.51	25[1)]	2.10 (Moderate)	Low

Note: [1)]Soil depth in the study plot was >100 cm and the tolerable erosion rate for hills or slope lands was 25 ton $ha^{-1}year^{-1}$ (Rahim 1995)

Table 11. The soil erosion in the different plantation systems

Planting system	Erosion (ton $ha^{-1}year^{-1}$)	Location	Researcher (year)
Monoculture agricultural	90.92	Krueng Simpo Sub Watershed, Aceh Province, Indonesia	Fitri (2011)
Soil and water conservation technique and application of agroforestry system	190.08	Ngadipiro Village, Nguntoronadi Sub-district, Wonogiri District, Central Java, Indonesia	Sumarno et al. (2011)
G. arborea + silt pit with 5 m distance	5.1	Banten, Indonesia	Pratiwi and Salim (2013)
G. arborea + silt pit with 10 m distance	5.6		
G. arborea + without silt pit (control)	5.9		
Agroforestry system of *A. cadamba* and *G. max*		East Kalimantan, Indonesia	This study
Slope of >15-25%	32.13		
Slope of >25-45%	52.51		

site was lower than those in monoculture agricultural (Fitri 2011) and application of agroforestry system (Sumarno et al. 2011) as presented in Table 11. This result implied that the mixed cropping of *A. cadamba* and *G. max* could be implemented for rehabilitating and conserving sloping lands.

The application of agroforestry system in different soil slopes is viable and useful based on the growth and hydro-orological parameters. The information on growth and hydro-orological aspects, as well as economic aspects, are important as the basic data for all stakeholders, including private parties and the government, in particular, the Ministry of Environment and Forestry and Ministry of Agriculture of the Republic of Indonesia which deal with the land rehabilitation and soil conservation programs.

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