BUKTI-BUKTI PROSES REVIEW (KORESPONDENSI)

Judul	:	The Mixed Cropping of *Anthocephalus cadamba* and *Glycine max* for Rehabilitating Sloping Lands
Penulis	:	Karyati, Sri Sarminah, Karmini, Gunawan Simangunsong, dan Jekson Tamba
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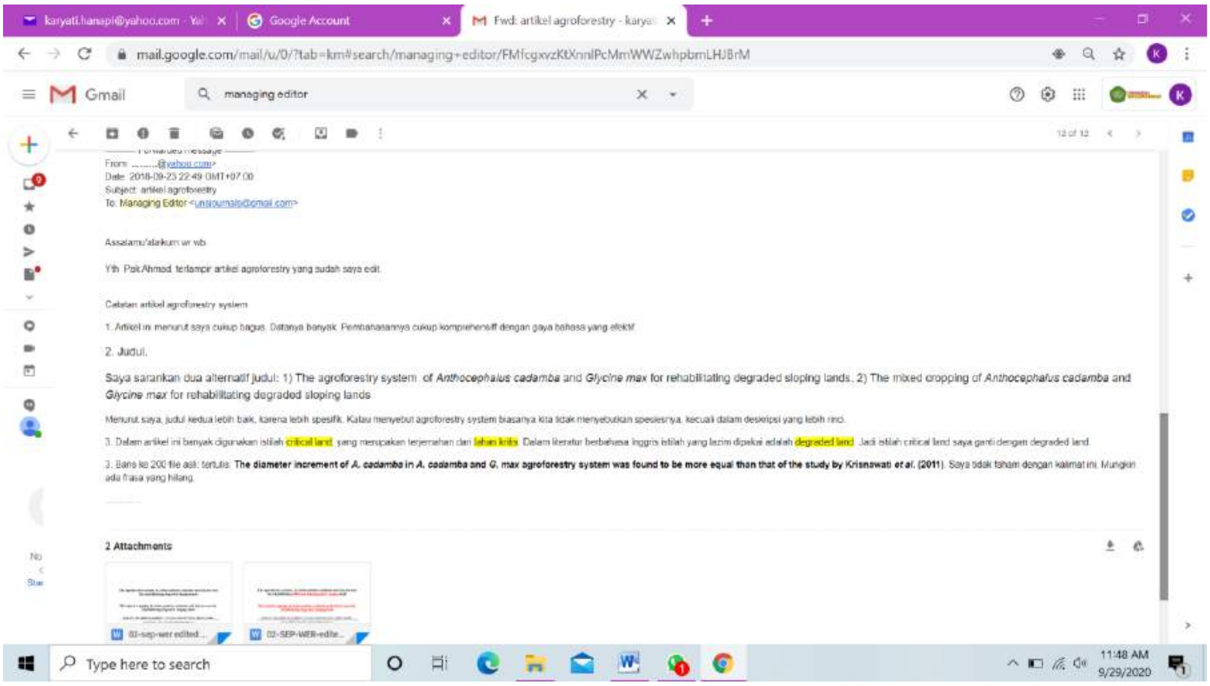

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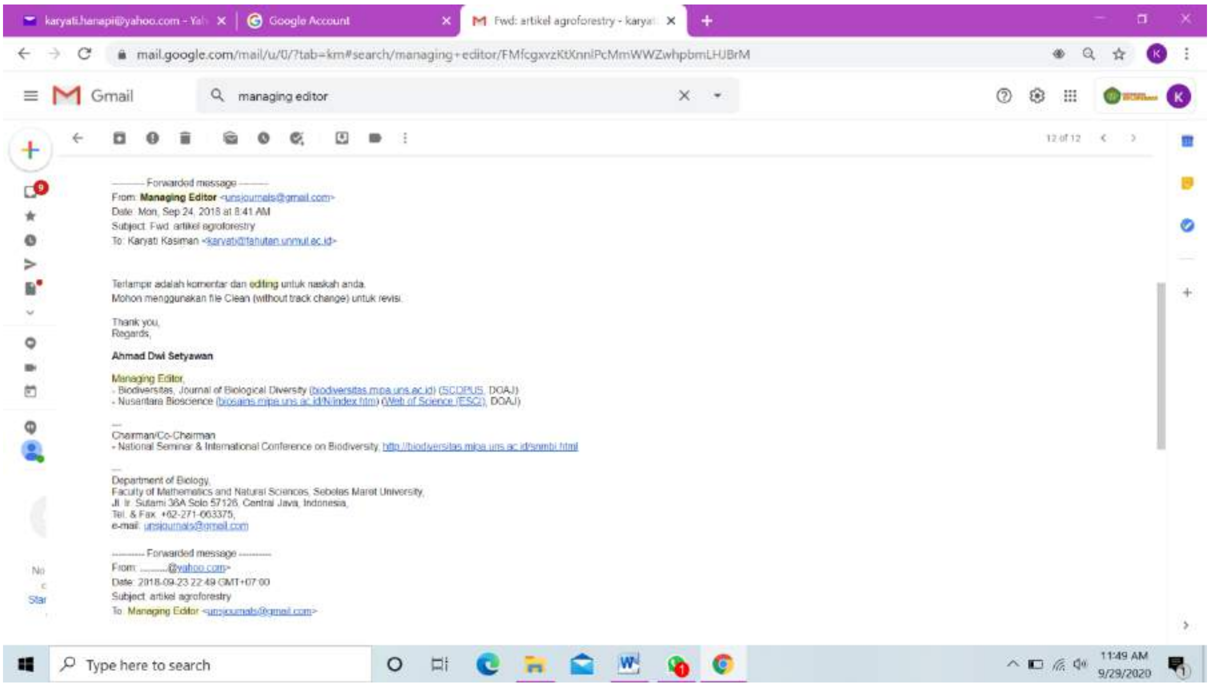

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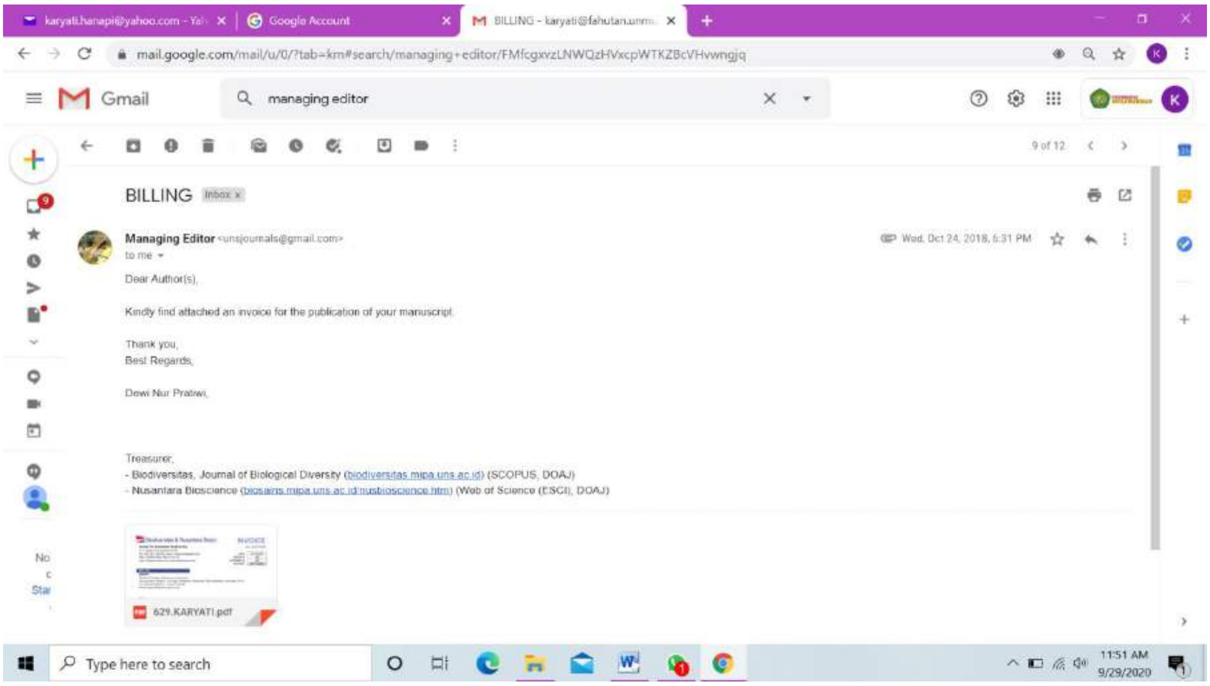

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The agroforestry system of *Anthocephalus cadamba* and *Glycine max* for rehabilitating ~~different slope~~degraded sloping lands

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

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Abstract. ~~The a~~Agroforestry system is one of the many alternatives to overcome problems concerning ~~critical~~ degraded lands. ~~For this reason, t~~The objectives of this current study were to implement the agroforestry system in the form of mixed cropping of *jabon* tree (*Anthocephalus cadamba* Mig) and soybean (*Glycine max* Merr) on degraded sloping land with different ~~soil slopes~~steepness (a slightly steep and a steep slope gradient) and to analyze the effect of that system on silvicultural and hydro-orological aspects of the degraded land. The silvicultural parameters (survival rate, ground coverage, diameter increment, and height increment) and hydro-orological parameters (surface run off, potential erosion, erosion hazard index, and erosion hazard level) were observed in this study. The findings showed that on the ~~land with~~ 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 (low) respectively. In the steeper ~~ground~~ slope (25-40%), the survival rate of *A. cadamba* reached 90%, the *G. max* coverage reached 60-69%, the diameter and the height increments of the *A. cadamba* reached 1.5 cm year^{-1} and 12.0 cm year^{-1} respectively. Furthermore, in the steep ~~ground~~slope, the potential erosion rate was 52.51 ton ha^{-1} year^{-1} and the erosion hazard index was 2.10 (moderate). In addition, the potential erosion rate and the erosion hazard index in the control plot were higher than~~compared to~~ those in slightly steep slope. Therefore, it could be implied that the application of *A. cadamba* and *G. max* mixed cropping ~~agroforestry~~ system could minimize the soil surface run off and the erosion rate effectively.

Key words: Erosion, growth, rehabilitation, slope, soil conservation

Running title: The agroforestry system for rehabilitating different slope lands

INTRODUCTION

The total area of degraded lands in Indonesia ~~cover~~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 ~~critical~~degraded areas have existed due to ~~the~~ biophysicals~~als~~, social, economic, and culturale 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 ~~to be able to~~capable of ~~overcome~~ 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 ~~Moreover, the role of~~ agroforestry system ~~is also to~~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 ~~by~~ using a combination of upland rice with soybean sequence and *Mucuna bracteata* strip is found ~~to be more~~ 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 ~~critical~~ degraded lands as alternative plants in the agroforestry system. These plant species ~~could~~ 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 ~~by~~ using agroforestry system in the form of *sengon* (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) mixed cropping are effective ~~to~~ 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 ~~shading~~ 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 ~~can~~ may be ~~possibly~~ implemented to ~~overcome~~ rehabilitate degraded lands. In addition to ~~its~~ providing economic benefit, the agricultural plant is expected to be able to cover the ground ~~soils~~ in the early years. Moreover, the forestry plant would be planted ~~to~~ 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 degraded sloping lands with different ~~soil slopes~~steepness (a slightly steep and a steep slope gradient) and to analyze the effect of that particular system on silvicultural and hydro-orological aspects of the land.

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MATERIALS AND METHODS

Study area

This study was carried out from March to October 2017 at a ~~slope~~ sloping land located in the Educational Forest of Mulawarman University Faculty of Forestry. The Educational Forest ~~itself~~ 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 ~~in~~ between the Samarinda- Bontang Highways between Kilometers 10 and 13. The map of the study area is shown in Figure 1.

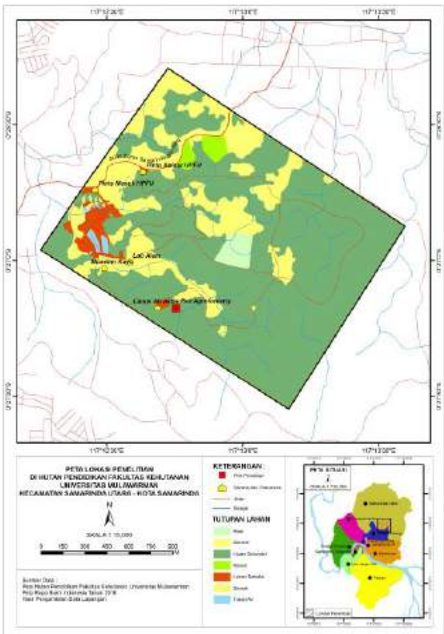

Figure 1. Location of study sites in Education Forest of Forestry Faculty of Mulawarman University at East Kalimantan, Indonesia.

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 ~~characterized to~~categorized as type A climate based on Schimdt-Ferguson classification system (1951), with a quotient (Q) of 0.048, which is considered as a very humid area with a tropical rain forest vegetation (Karyati *et al.* 2016).

The Mulawarman University Educational Forest is located about 50 m above sea level in a lowland tropical rainforest. The original vegetation ~~included~~ was ~~a~~ natural forest dominated by Dipterocarpaceae. After the forest fire incidents in 1983, 1993, and 1998, the forest land ~~grew towards~~turned into ~~an~~ early secondary forest. Nowadays, the forest ~~has been~~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 walichii*), *medang* (*Litsea* spp.), and *meranti* (*Shorea* spp.) are predominantly found in the forest. In addition, animals of invertebrates (protozoas, annelids, mollusks, crustaceans, insects, and arachnoids) and vertebrates (fishs, frogs, birds, reptiles, and mammals) are also found in this area (KRUS 2013; KRUS 2014).

Instruments and materials

The tools and instruments employed in this study were Global Positioning System (GPS) equipments, measuring tapes, clinometers, compasses, diameter tapes (phi-band), microcalipers, machetes, hoes, sickles, galvanized zinc roof sheets, PVC pipes, drums, rulers, soil sampling rings, ombrometers, graduated cylinders, filter paper, buckets, hand sprayers, a camera, and stationery.

Procedures

Two experimental plots of 10 m × 10 m were established ~~for~~ in two different slope classes in the Educational Forest area, namely a slightly steep slope (15-25%) and a steep slope (25-40%). *A. cadamba* and *G. max* were grown on both plots. *A. cadamda* trees were planted with a spacing of 3 m × 3 m whereas *G. max* ~~was~~ were planted ~~in~~ between *A. cadamba* trees as the groundcover legumes. 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 ~~flat~~ moderate slope (8-15%) ~~and with no grown~~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, fertiliz~~er applic~~ation, and pest and plant diseases control, was performed regularly. The harvesting was only done for *G. max* ~~yield~~ whereas there was no harvesting done for the *A. cadamba* trees.

Data ~~analysis~~analyses

Soil properties

To obtain the soil profile description, a soil pit with the depth of 1.5 m was dug at the centere 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 ~~moving towards~~from the topsoil through the bottom of profile were observed. Some of the characteristics, such as depth and field texture, were ~~distinguished~~described. The ~~analysis~~ 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 ~~by~~ using the glass electrode method. The total nitrogen (total N) was analyzed ~~by~~ using Kjeldahl method whereas Soil P and K were analyzed ~~by~~ using the Bray 1 method.

Erosion hazard index

The observation and measurement of silvicultural parameters were done at the end of every month for four months. The observation was conducted for both *A. cadamba* and *G. max* ~~plants~~. *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 ~~Table~~ 2 below, while the erosion hazard index was determined ~~by~~ using the following equation (Hammer 1981):

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

Table 1. Erosion hazard index categories.

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

Source: Hammer (1981)

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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)

RESULTS AND DISCUSSION

Silviculture aspects

In general, *A. cadamba* and *G. max* grew well ~~and healthily~~ in different slope~~ lands~~, 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 criteria of plant growth were formulated based on Regulation of Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009, which states that a healthy plant is a plant which grows ~~freshly~~ robustly with normal and straight stems, with fresh green leaves, as well as without pests, diseases, and weeds. The growth parameters of *A. cadamba* and *G. max* are summarized in Table 3.

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 (25-40%)			
	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

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 were ~~observed to be better~~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 ~~study~~ studies in monoculture system (Dogbe *et al*. 2013) and agroforestry system (Jauhari *et al*. 2016; Karmini *et al*. 2017). Yet, 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 comparison of *G. max* yields of monoculture and agroforestry system ~~is~~ are presented in ~~the following~~ Table 4.

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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	4142.5 kg ha^{-1}	Research Farm of Mustafa Kemal University, Hatay, Turkey	Caliskan *et al*. (2007)
A 30-cm row width in double-cropped soybean	3241.5 kg ha^{-1}		
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. (2016)
Variety of Argomulyo	0.72 ton ha^{-1}		
Variety of Anjasmoro	1.15 ton ha^{-1}		
Variety of Grobogan	0.64 ton ha^{-1}		
Variety of Wilis	0.56 ton ha^{-1}		
Non-agroforestry			
Variety of Argomulyo	0.62 ton ha^{-1}		
Variety of Anjasmoro	0.90 ton ha^{-1}		
Variety of Grobogan	0.42 ton ha^{-1}		
Variety of Wilis	0.35 ton 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*	1604 kg ha^{-1} 1568 kg ha^{-1}	East Kalimantan 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 (25-40%)	485 kg ha^{-1}		

Tables 5 and 6 illustrate the monthly diameter and ~~the~~ height increments of *A. cadamba* trees that were monitored for four months. *A. cadamba* trees on the slightly steep slope showed better growth performance in terms of diameter and height increment ~~compared with~~than those on the steeper slope. The average stem diameter increments of *A. cadamba* ~~located on the less steep~~ 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.

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

Tree number	Slightly steep slope (15-25%)					Steep slope (25-40%)				
	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 number	Slightly steep slope (15-25%)					Steep slope (25-40%)				
	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

Tree number	Slightly steep slope (15-25%)					Steep slope (25-40%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
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.

The diameter increment of *A. cadamba* in *A. cadamba* and *G. max* agroforestry system was found to be more equal than that of the study 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 were 1.2-4.8 cm year^{-1} and 0.8-3.7 m year^{-1} respectively. In comparison, 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 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 ~~lands~~ than those in a less steep slope. The slope steepness might also influence the groundcover crop growth, i.e. the *G. max* ~~plant~~. Moreover, the ground coverage of the *G. max* on the steep plot was found to be lower than that on the slightly steep ~~ground~~plot.

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The *G. max* might indirectly influence the diameter and height growth~~s~~ of the *A. cadamba* ~~trees~~. It is likely that the *G. max* ~~plants~~ supplied additional organic materials through the decomposition of leaf litter~~falling leaves~~. This process contributed an extra source of organic materials for the growth of the *A. cadamba* ~~tree~~. Interestingly, the chemical ~~analysis~~ 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.

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)

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 ~~events~~. 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.

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

Rain event	Rainfall (mm)	Surface runoff (l)		
		Control Plot (8-15%)	Slightly steep slope (15-25%)	Steep slope (25-40%)
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 (gr)		
		Control Plot (8-15%)	**Slightly steep slope (15-25%)**	**Steep slope (25-40%)**
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

Rain event	Rainfall (mm)	Eroded soil mass (gr)		
		Control Plot (8-15%)	**Slightly steep slope (15-25%)**	**Steep slope (25-40%)**
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 results above indicated that the steeper the slope, the higher the surface runoff volume and the eroded soil mass. In the steeper slope lands, the rainfall ~~flew~~ flowed to the lower ~~surface lands~~area faster and more easily. It ~~would~~ 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 & LeBissonnais 2000). In addition, the ~~soil~~ slope steepness and ~~land~~ length ~~influenced~~ influence the potential soil erosion. The erosion rate ~~was~~ is also affected by soil properties, especially soil texture. The soil texture in the study site is sandy loam characterized by the fine texture as presented in Table 7 ~~previously~~. This soil ~~texture~~ 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 whether the erosion is ~~in~~ at a threatening level or is hazardous for a land. For sloping lands, the tolerable soil loss ~~would be~~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 showed in Table 10 ~~below~~. The soil erosion rate of agroforestry system of *A. cadamba* and *G. max* on different slope lands in the study 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 agroforestry system of *A. cadamba* and *G. max* could be implemented for rehabilitation and soil conservation of degraded land with different slope conditions.

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	25-40%	1330.89	52.51	25[1)]	2.10 (Moderate)	Low

[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	Desa Ngadipiro, Kecamatan Nguntoronadi,	Sumarno *et al*. (2011)

		Kabupaten Wonogiri, Indonesia	
G. arborea + silt pit with 5 m distance *G. arborea* + silt pit with 10 m distance *G. arborea* + without silt pit (control)	5.1 5.6 5.9	Banten, Indonesia	Pratiwi and Salim (2013)
Agroforestry system of *A. cadamba* and *G. max* Slope of 25-40% Slope of >40%	32.13 52.51	East Kalimantan, Indonesia	This study

The application of agroforestry system in different soil slopes is viable and useful based on the silvicultural and hydro-orological parameters. The information on silvicultural 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 deals with the land rehabilitation and soil conservation programs.

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The agroforestry system of *Anthocephalus cadamba* and *Glycine max* for rehabilitating different slope lands

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Abstract. *Karyati, Sarminah S, Karmini, Simangunsong G, Tamba J. 2018. The agroforestry system of Anthocephalus cadamba and Glycine max for rehabilitating different slope lands. Biodiversitas x: xx-xx.* The agroforestry system is one of the many alternatives to overcome problems concerning critical lands. For this reason, the objectives of this current study were to implement the agroforestry system of jabon (*Anthocephalus cadamba* Mig) and soybean (*Glycine max* Merr) on degraded land with different soil slopes (a slightly steep and a steep slope gradient) and to analyze the effect of that system on silvicultural and hydro-orological aspects of the degraded land. The silvicultural parameters (survival rate, ground coverage, diameter increment, and height increment) and hydro-orological parameters (surface run off, potential erosion, erosion hazard index, and erosion hazard level) were observed in this study. The findings showed that on the land with slightly steep slope (15-25%), 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 (low)~~,~~ respectively. In the steeper ground (25-40%), the survival rate of *A. cadamba* reached 90%, the *G. max* ground cover~~coverage~~ reached 60-69%, the diameter and ~~the~~ height increments of the *A. cadamba* reached 1.5 cm year^{-1} and 12.0 cm year^{-1}~~,~~ respectively. Furthermore, in the steep ground, the potential erosion rate was 52.51 ton ha^{-1} year^{-1} and the erosion hazard index was 2.10 (moderate). In addition, the potential erosion rate and the erosion hazard index in the control plot were higher as compared to those in slightly steep slope. Therefore, it could be implied that the application of *A. cadamba* and *G. max* agroforestry system could minimize the soil surface run off and the erosion rate effectively.

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Key words: Erosion, growth, rehabilitation, slope, soil conservation

Running title: The agroforestry system for rehabilitating different slope lands

INTRODUCTION

The degraded lands in Indonesia cover approximately 78 million ha, which consist 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 critical areas have existed due to the biophysics, social, economic~~,~~ and ~~culture~~ 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 proven to be able to overcome 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). Moreover, the role of agroforestry system is also to 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 by using a combination of upland rice with soybean sequence and *Mucuna bracteata* strip is found to be more 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 critical lands as alternative plants in the agroforestry system. These plant species could 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 by using agroforestry system of sengon (*Falcataria moluccana*) and peanut (*Arachis hypogaea*) are effective to suppress erosion rate to a low erosion hazard (Sarminah *et al*. 2018). The production of soybean (*Glycine max* Merr), which is a tolerant shading 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 can be possibly implemented to overcome degraded lands. In addition to its economic benefit, the agricultural plant is expected to be able to cover the ground soils in the early years. Moreover, the forestry plant would be planted to soil and water conservation in long term program. Therefore, the objectives of this study were to implement the agroforestry system of *A. cadamba* and *G. max* on degraded land with different soil slopes (a slightly steep and a steep slope gradient) and to analyze the effect of that particular system on silvicultural and hydro-orological aspects of the land.

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Is the purpose of the study is to implement agroforestry system on degraded land with different slope?

MATERIALS AND METHODS

Study area

This study was carried out from March to October 2017 at a slope land located in the Educational Forest of Mulawarman University Faculty of Forestry. The Educational Forest itself 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 in between the Samarinda- Bontang Highways Kilometers 10 and 13. The map of the study area is shown in Figure 1.

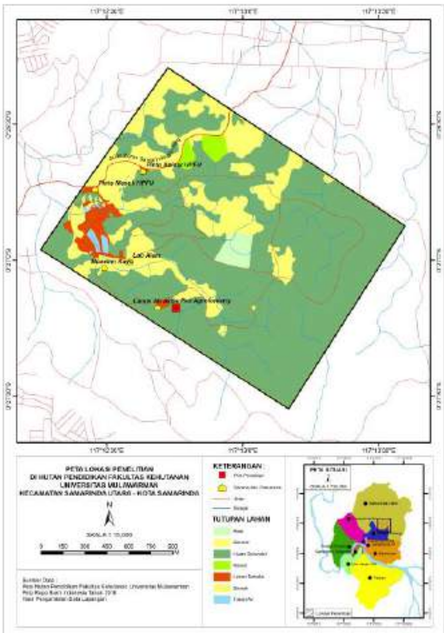

Figure 1. Location of study sites in Education Forest of Forestry Faculty of Mulawarman University at East Kalimantan, Indonesia.

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

Commented [WU11]: Does the rainfall pattern in the area is constant throughout the year?
Tropical area is subjected to monsoon season. How about in the study area: any raining season in the area? If so, it should be good to include the monthly rainfall data/ trend for better clarification on the climate in the study area.

Municipality is characterized to type A climate based on Schimdt-Ferguson classification system (1951), with a quotient (Q) of 0.048, which is considered as a very humid area with a tropical rain forest vegetation (Karyati *et al*. 2016).

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

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Instruments and materials

The tools and instruments employed in this study were Global Positioning System (GPS), measuring tape, clinometer, compass, diameter 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.

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Procedures

Two experimental plots of 10 m × 10 m were established for two different slope classes in the Educational Forest area, namely a slightly steep slope (15-25%) and a steep slope (25-40%). *A. cadamba* and *G. max* were grown on both plots. *A. cadamda* trees were planted with a spacing of 3 m × 3 m whereas *G. max* was planted in between *A. cadamba* trees as the groundcover legumes. 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 flat slope (8-15%) and with no grown plantation. Furthermore, the hydro-orological parameters measurements were conducted for 35 times 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, fertilizer application, and pest and plant diseases control, was performed regularly. The harvesting was only done for *G. max* yield whereas there was no harvesting done for the *A. cadamba* trees.

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How aboth the landform attributes for both plots, were they the same between them as compared to the control plot? Explain specifically in this section.

Were the land where these plots were located classified as degraded land (as referred in the statment of the study objective).

Did you established control plot in slightly steep and steep slope area without any plants planted? It would be better to compare the rate of erosion from plots with or without planting at similar slope classes.

Data analysis

Soil properties

To obtain the soil profile description, a soil pit with the depth of 1.5 m was dug at the centre 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 moving towards the bottom of profile were observed. Some of the characteristics, such as depth and field texture, were distinguished. The analysis 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 by using the glass electrode method. The total nitrogen (total N) was analyzed by using Kjeldahl method whereas Soil P and K were analyzed by using the Bray 1 method.

Erosion hazard index

The observation and measurement of silvicultural parameters were done at the end of every month for four months. The observation was conducted for both *A. cadamba* and *G. max* plants. *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 Table 1 and Table 2 below while the erosion hazard index was determined by using the following equation (Hammer 1981):

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

Table 1. Erosion hazard index categories.

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

Source: Hammer (1981)

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)

RESULTS AND DISCUSSION

Silviculture aspects

In general, *A. cadamba* and *G. max* grew well and healthily in different slope lands, 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 criteria of plant growth were formulated based on Regulation of Ministry of Forestry Republic of Indonesia Number: P.60/Menhut-II/2009, which states that a healthy plant is a plant which grows freshly with normal and straight stems, with fresh green leaves, as well as without pests, diseases, and weeds. The growth parameters of *A. cadamba* and *G. max* are summarized in Table 3.

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 (25-40%)			
	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

Based on the observation, it was found that the number of healthy plant 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 were observed to be better 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 study in monoculture system (Dogbe *et al*. 2013) and agroforestry system (Jauhari *et al*. 2016; Karmini *et al*. 2017). Yet, 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 comparison of *G. max* yield of monoculture and agroforestry system is presented in the following Table 4.

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	4142.5 kg ha^{-1}	Research Farm of Mustafa Kemal University, Hatay, Turkey	Caliskan *et al*. (2007)
A 30-cm row width in double-cropped soybean	3241.5 kg ha^{-1}		
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. (2016)
Variety of Argomulyo	0.72 ton ha^{-1}		
Variety of Anjasmoro	1.15 ton ha^{-1}		
Variety of Grobogan	0.64 ton ha^{-1}		
Variety of Wilis	0.56 ton ha^{-1}		
Non-agroforestry			
Variety of Argomulyo	0.62 ton ha^{-1}		
Variety of Anjasmoro	0.90 ton ha^{-1}		
Variety of Grobogan	0.42 ton ha^{-1}		
Variety of Wilis	0.35 ton ha^{-1}		

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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*	1604 kg ha^{-1} 1568 kg ha^{-1}	East Kalimantan Indonesia	Statistics of Indonesia (2017)
Agroforestry system of *A. cadamba* and *G. max* Slightly steep slope (15-25%) Steep slope (25-40%)	 525 kg ha^{-1} 485 kg ha^{-1}	Educational Forest of Forestry Faculty, Mulawarman University, Samarinda, East Kalimantan, Indonesia	This study

Tables 5 and 6 illustrate the monthly diameter and the height increments of *A. cadamba* trees that were monitored for four months. *A. cadamba* trees on the slightly steep slope showed better growth performance in terms of diameter and height increment compared with those on the steeper slope. The average stem diameter increments of *A. cadamba* located on the less steep were 1.8 cm year^{-1} and 1.5 cm year^{-1} on the steep slope 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.

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

Tree number	Slightly steep slope (15-25%)					Steep slope (25-40%)				
	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 number	Slightly steep slope (15-25%)					Steep slope (25-40%)				
	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

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Tree number	Slightly steep slope (15-25%)					Steep slope (25-40%)				
	H_0	h_1	h_2	h_3	h_4	H_0	h_1	h_2	h_3	h_4
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.

The diameter increment of *A. cadamba* in *A. cadamba* and *G. max* agroforestry system was found to be more equal than that of the study 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 were 1.2-4.8 cm $year^{-1}$ and 0.8-3.7 m $year^{-1}$ respectively. In comparison, 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 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 lands than those in a less steep slope. The slope steepness might also influence the groundcover crop growth, i.e. the *G. max* plant. Moreover, the ground coverage of the *G. max* on the steep plot was found to be lower than that on the slightly steep ground.

The *G. max* might indirectly influence the diameter and height growths of the *A. cadamba* trees. It is likely that the *G. max* plants supplied additional organic materials through the decomposition of falling leaves. This process contributed an extra source of organic materials for the growth of the *A. cadamba* tree. Interestingly, the chemical analysis 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.

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)

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 events. 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.

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

Rain event	Rainfall (mm)	Surface runoff (l)		
		Control Plot (8-15%)	Slightly steep slope (15-25%)	Steep slope (25-40%)
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

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Commented [WU25]: If so, state the relevant ebidance to support this statement

Commented [WU26]: This comparison was made based on the physicochemical properties of the soils studied. The question here is, was the soil collected relatively at the same constant sampling points for this comparion?

Commented [WU27]: It seems that in the event of high rainfall, the amount of surface runoff varied widely. Normal understanding is that the higher the amount of rain, the higher the amount of surface runoff is to be expected and vice versa in which, was not the case in this study.
It should be very interesting to highlight this points for better clarification of the work and at the same time, aligned to the objective of this research work.

Commented [WU28]: What is the unit for the surface runoff measurement? Per hectare basis?

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.

		Eroded soil mass (gr)		
Rain event	**Rainfall (mm)**	**Control Plot (8-15%)**	**Slightly steep slope (15-25%)**	**Steep slope (25-40%)**
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

Rain event	Rainfall (mm)	Eroded soil mass (gr)		
		Control Plot (8-15%)	**Slightly steep slope (15-25%)**	**Steep slope (25-40%)**
Mean	17.41	955.70	642.62	1050.31

The results above indicated that the steeper the slope, the higher the surface runoff volume and the eroded soil mass. In the steeper slope lands, the rainfall flew to the lower surface lands faster and more easily. It would lead 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 & LeBissonnais 2000). In addition, the soil slope and land length influenced potential soil erosion. The erosion rate was also affected by soil properties, especially soil texture. The soil texture in the study site is sandy loam characterized by the fine texture as presented in Table 7 previously. This soil texture 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 whether the erosion in a threat level or is hazardous for a land. For sloping lands, the tolerable soil loss would be 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 showed in Table 10 below. The soil erosion rate of agroforestry system of *A. cadamba* and *G. max* on different slope lands in the study site was lower than those in monoculture agricultural (Fitri 2011) and application of agroforestry system (Sumarno *et al. 2*011) as presented in Table 11. This result implied that agroforestry system of *A. cadamba* and *G. max* could be implemented for rehabilitation and soil conservation of degraded land with different slope conditions.

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	25-40%	1330.89	52.51	25[1)]	2.10 (Moderate)	Low

[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	Desa Ngadipiro, Kecamatan Nguntoronadi, Kabupaten Wonogiri, 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 25-40%	32.13		
Slope of >40%	52.51		

The application of agroforestry system in different soil slopes is viable and useful based on the silvicultural and hydro-orological parameters. The information on silvicultural 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 deals with the land rehabilitation and soil conservation programs.

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Title of manuscript:

The agroforestry system of *Anthocephalus cadamba* and *Glycine max* for rehabilitating different slope lands

General comments:

1. The paper highlights the agroforestry system of *Anthocephalus cadamba* and *Glycine max* for rehabilitating different slope lands. Such study is very important in order to provide in-sights on the contribution towards the development of agroforestry systems in Indonesia towards combating soil erosion probability under a specific land use area for land restoration purposes.
2. Such study falls within the scope of this Journal and of reference for readers, especially policy makers in Indonesia in their development planning especially in the development of agriculture sector in East Kalimantan, Indonesia.
3. Having said that, I have a few comments which requires feedback/ revision from the authors before the manuscript can be considered for publication in this journal. Kindly refer to the comments in the manuscript for the authors perusals.
4. Some explanations on the findings were not stated clearly in the manuscript especially the experimental design of the work. Furthermore, the period of the study and number of replications for each assessed plots should be considered as well as I find it will be difficult to express the relevance of the work to answer the study objectives with very limited number of replications. Having said that, if the author could highlight the constraint in establishing more replicate plots for the assessment in the manuscript, the explanation and discussion of the findings can be tolerated hence, allow better view among readers on the experimental design. Detail inquiries on the data are stated in the comments in the manuscript.
5. If possible, the usage of English language in this manuscript needs improvement to allow better understanding among readers of this journal. Grammatical mistakes in the manuscript were quite glaring which requires some paraphrasing and improvements.

Decision: Accepted for publication after major corrections

Samarinda, 14 Oktober 2018

Dear Managing Editor

Bersama ini kami sampaikan beberapa perbaikan pada manuskrip terlampir.

The comment on review of manuscript “The agroforestry system of *Anthocephalus cadamba* and *Glycine max* for rehabilitating sloping lands”.

No. Comments	Page/Line	Review	Feedback and revision
Reviewer 1 (19 September 2018)			
1 & 2	Judul	Add → Mig and Merr	Telah ditambahkan.
3	Abstrak, hal. 1, baris 12	To implement is not measurable. Use suitable terms.	Kalimat telah diperbaiki.
4	Abstrak, hal. 1, baris 14	Silvicultural → growth	Telah diperbaiki.
5 & 6	Abstrak, hal. 1, baris 19 & 21	What do (low) and (moderate) here means?	Low dan moderate termasuk kelas indeks bahaya erosi → Telah dihilangkan.
7	Abstrak, hal. 1, baris 23 & 24	Such statement too speculative ...	Kalimat telah diperbaiki.
8, 9 & 10	Hal. 2, baris 54-59	Revise the sentences, not clear	Kalimat telah diperbaiki.
11	Hal. 2, baris 104	Does the rainfall pattern in the area is constant throughout the year? ...	Data curah hujan yang disajikan adalah data rataan bulanan. Kami tidak menyajikan data/trend curah hujan bulanan, dan hanya menyajikan data 35 kejadian hujan sepanang pengukuran erosi (Tabel 8).
12	Hal. 3, baris 113-115	Rephrase these sentences. Did not provide clear statement.	Kalimat telah diperbaiki.
13	Hal. 3, baris 119-122	Not necessary to be included in the manuscript.	Kalimat telah dihilangkan.
14	Hal. 3, baris 123-124	The methodology for the parameter assessed ...	Penilaian dan pengukuran parameter pertumbuhan telah ditambahkan.
15	Hal. 3, baris 123-132	• What are the age stands for both of the experimental plots?	• Umur tegakan *A. cadamba* sekitar 6 bulan telah ditambahkan dalam penjelasan.
		• How about the landform attributes for both plots, were they	• Plot berada pada kelas kelerengan agak curam (>15-25%) dan curam (>25-45%), sedangkan plot kontrol pada kelas kelerengan landai (>8-15%).
		• Were the land where these	• Kami telah menghilangkan

No. Comments	Page/Line	Review	Feedback and revision
		plots were	kata ‘degraded” pada plot penelitian.
		• Did you established control plot	• Plot kontrol (tanpa penanaman) dibuat pada kelas kelerengan landai (>8-15%) sebagai perbandingan, sehingga terdapat 3 kelas kelerengan berbeda.
16	Hal. 4, baris 162	?	Kata ‘healthily’ telah dihilangkan.
17	Hal. 4, baris 164-166	This criteria inclusive for both *A. cadamba* dan *G. max*?	Kriteria ini untuk tumbuhan secara umum.
18	Hal. 4, baris 164-166	The part should be explain clearly in the Methodology section.	Bagian ini telah dihilangkan dan dipindah ke bagian ‘Materials and Methods’, section ‘Procedures’.
19	Hal. 4, tabel 3	The methods in getting the percentage values for each parameters here should be explained clearly in the Methodology section.	Penjelasan telah ditambahkan.
20	Hal. 4, tabel 4	Convert all values to kg ha^{-1}	Konversi telah dilakukan.
21	Hal. 5, baris 184-185	Any statistical comparisons made?	Kata ‘better’ diganti dengan kata ‘faster”.
22 & 23	Hal. 5, Tabel 5 & 6	The presentation of this data will be suitable in Figure form using the average and SD values only.	Penggunaan tabel dianggap lebih memudahkan untuk melihat pertumbuhan diameter dan tinggi tanaman *A. cadamba* dari bulan ke bulan selama pengamatan.
24	Hal 6, baris 203-204	Was this statement for the purpose of comparing the diameter increment of only *A. cadamba* trees for both studies?	Kami telah menghilangkan kata ‘in comparison’ dan menggantinya dengan kata ‘similarly’.
25	Hal. 6, baris 209	If so, state the relevant evidence to support this statement.	Kami telah menghilangkan kalimat tersebut.
26	Hal 6, baris 218	This comparison was made based on the physicochemical properties of the soils studied. The question here is, was the soil collected relatively at the same constant sampling points for this comparison?	Pengambilan sampel tanah untuk pengujian sifat kimia tanah dilakukan pada titik sampling yang sama.
27	Hal 6, baris 224-226	It seems that in the event of	Kami telah menambahkan

No. Comments	Page/Line	Review	Feedback and revision
		high rainfall, the amount of surface runoff varied widely.......	penjelasan faktor-faktor yang mempengaruhi erosi tanah.
28	Hal 6, Tabel 8 & 9	What is the unit for the surface runoff measurement? Per hectare basis?	Telah ditambahkan penjelasan → per 30 m^2 → pada Tabel 8 dan 9.
Reviewers 2 (23 September 2018)			
1		Pembahasan cukup komprehensif.	
2		Saran: dua alternatif judul	Kami setuju menggunakan judul kedua.
3		Istilah ‘critical land’ diganti ‘degraded’	Kami setuju dan menekankan penelitian pada lahan berlereng, sehingga beberapa istilah ‘degraded land” kami hilangkan. Mohon bantuan editor untuk mengecek lebih lanjut.
4		Baris ke 200 file asli: tertulis: *The diameter increment of A. cadamba in *A. cadamba* and *G. max* agroforestry system was found to be more equal than that of the study by Krisnawati et al. (2011)*. Saya tidak faham dengan kalimat ini. Mungkin ada frasa yang hilang.	Kami telah memperbaiki kalimat tersebut.
Authors			
	Manuskrip		Kami telah menghilang kata ‘degraded’ pada judul manuskrip dan menekankan plot penelitian pada lahan berlereng.
	Hal. 2, Gambar 1		Gambar peta telah diganti.

Samarinda, 14 Oktober 2018

Karyati

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OFFICIAL STATEMENT OF MANUSCRIPT PROOFREADING

I, the undersigned, hereby certify that the article manuscript entitled 'THE AGROFORESTRY SYSTEM OF ANTHOCEPHALUS CADAMBA AND GLYCINE MAX FOR REHABILITATING DIFFERENT SLOPE LANDS' by the following authors: Karyati, Sri Sarminah, Karmini, Gunawan Simangunsong, and Jekson Tamba, has been checked and edited by a specialist proofreader with suitable professional knowledge at our Language Center.

Mulawarman University Language Center,

Dr.phil. Maria Teodora Ping, M.Sc.

Secretary

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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: xxxx.* 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).

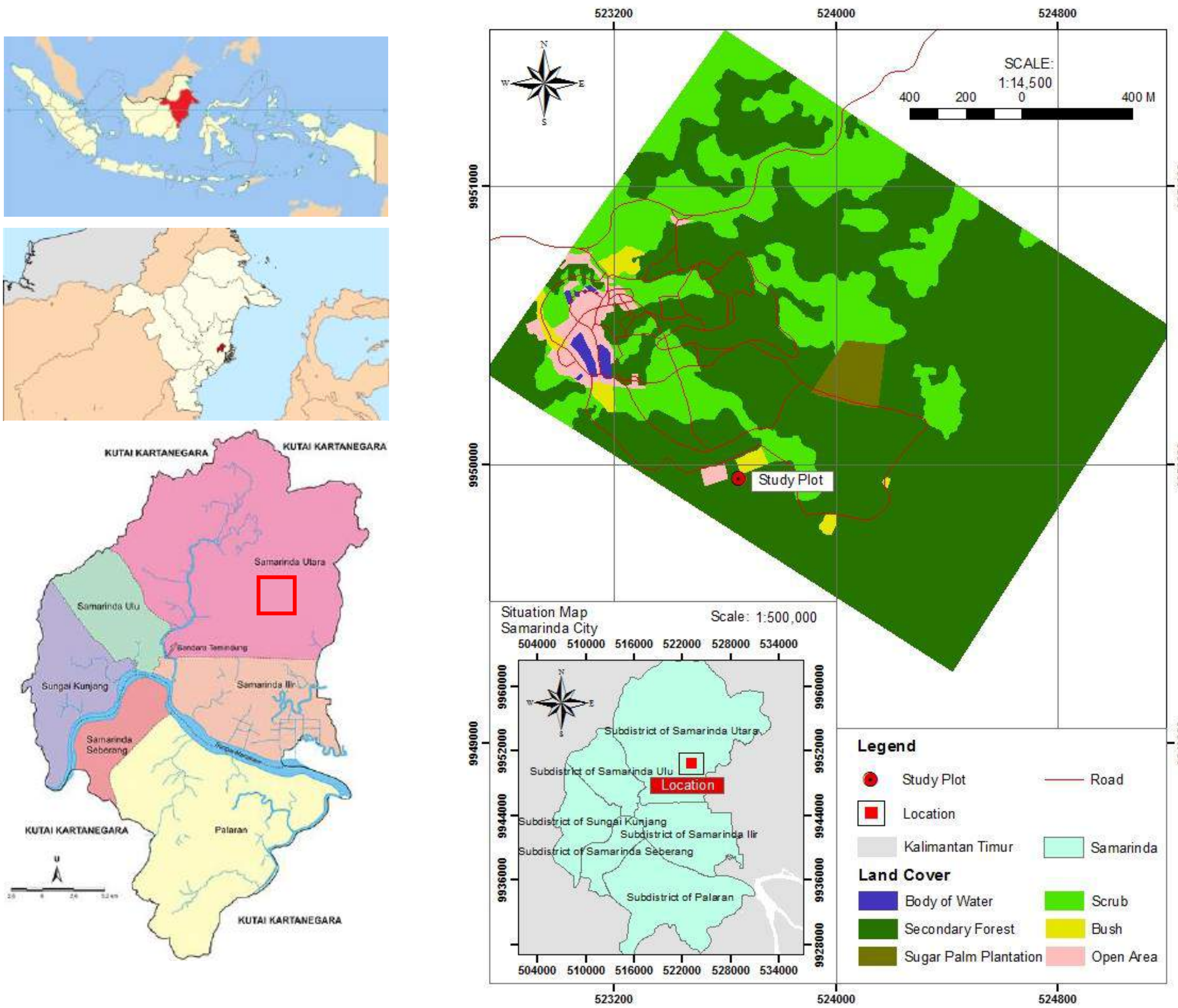

Figure 1. Location of study site in Education Forest of Forestry Faculty of Mulawarman University at East Kalimantan, Indonesia

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):

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

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	4,142.5 kg ha^{-1}	Research Farm of Mustafa Kemal	Caliskan et al. (2007)
A 30-cm row width in double-cropped soybean	3,241.5 kg ha^{-1}	University, Hatay, Turkey	
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,	Jauhari et al. (2016)
Variety of Argomulyo	720 kg ha^{-1}	Kampus IPB, Dramaga, Bogor	
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}	East Kalimantan	Statistics of Indonesia
	1568 kg ha^{-1}	Indonesia	(2017)
Agroforestry system of *A. cadamba* and *G. max*		Educational Forest of Forestry	This study
Slightly steep slope (>15-25%)	525 kg ha^{-1}	Faculty, Mulawarman University,	
Steep slope (>25-45%)	485 kg ha^{-1}	Samarinda, East Kalimantan, Indonesia	

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 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

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

Tree number	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 number	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)

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. 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).

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

Rain event	Rainfall (mm)	Eroded soil mass ($g/30\ m^2$) 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

Rain event	Rainfall (mm)	Eroded soil mass ($g/30\ m^2$) 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

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

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 site was lower than those in monoculture agricultural (Fitri 2011) and application of agroforestry system (Sumarno et al. *2*011) 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.

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

[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		

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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