SURFACE RUNOFF AND SOIL ORGANIC MATTER AVAILABILITY IN BAMBOO-BASED AGROFORESTRY IN LOMBOK TIMUR DISTRICT

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ABSTRACT

Bamboo-based agroforestry is suitable for soils which are poor in nutrient. The characteristics of bamboo and the rapid closure of its canopy improve soil cover, soil nutrient availability and soil moisture content, and prevent erosion by reducing surface runoff. The research was aimed at determining the factors that influenced surface runoff and the availability of soil organic matter (SOM) in the bamboo-based agroforestry in East Lombok. Research was done from March 2010 to March 2011 in Lenek Daya village, Aikmel sub-district, East Lombok district. The research plots were located on slopes of 0-15°, 30-45°, and 45-65°; with bamboo canopy closures of 0-25%, 25-50%, 50-75%, and over 75%. The research involving 12 plots, each in 4 x 12 m size. Measurements included surface runoff, bamboo canopy closure, weeds and bamboo leaves litter weight, rainfall depth and duration, dissolved sediment, and soil physical and chemical properties as well as SOM. Correlation and multiple linear regression tests were used in data analysis. The results of the regression tests showed a change in surface runoff which was influenced by changes in bamboo canopy closure, rain duration, rain intensity and soil sand fraction, each by -0.019, 0.418, 0.049 and -0.065 respectively. Rain duration was the highest influencing variable, whereas bamboo canopy closure significantly decreased surface runoff. Bamboo canopy closure had no correlation with the increase of SOM. But, the increase of SOM had correlation with the increase of soil cation exchange capacity (CEC). The positive impact of bamboo canopy closure on Regosol soil fertility in bamboo-based agroforestry land was determined by land management intensity which could increase the availability of SOM and decrease phosphorus element loss due to leaching of nutrient.

Keywords: Agroforestry, bamboo, surface runoff, soil organic matter

I. INTRODUCTION

Critical land is the result of forest degradation, it has an adverse effect in the form of flash floods, landslides and reduced water resources in some areas at the Province of West Nusa Tenggara (Dinas Kehutanan NTB, 2009). Moreover, it leads to the deficit of water availability in the two of three watersheds in Lombok island (West Nusa Tenggara), Dodokan and Menanga, i.e. -2,156.89 and -258.15 million m^3 respectively. In addition to the deficit of water availability, the highly porous young soil type (Regosol) in most areas of the island of Lombok presents an obstacle to the successful cultivation of crops.

Bamboo populations are widely spread over the island of Lombok, it reaches an area of 2,365 ha with a potential of 4.257 million rods (Markum *et al.*, 2007*)*. In East Lombok, particularly in research sites, bamboo is planted along the boundaries, in rows or in a specified part of the land, separated from agricultural crops. These are different bamboo plantation types, which form agroforestry patterns and have been developed for generations. Farmers argue that the presence of bamboo closure in the cultivation land reduces the productivity of agricultural crops. However, bamboo is planted because it is able to grow on limited water resources, it is easy to cultivate, it

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yields continuous harvest and its marketable (Handoko, 2009).

Dry land farming systems by small farmers is the agricultural base in Nusa Tenggara. Agroforestry in Nusa Tenggara is generally developed on barren and small land (0.25 to 1 ha) under the ownership of individual farmers (Roshetko *et al.*, 2001). Bamboo plantation is ecologically capable of accelerating the canopy closure of degraded lands, improving nutrient availability and reducing runoff (Nath *et al.*, 2009). Productivity of agricultural crops will be low in the presence of bamboo (Divakara *et al.*, 2001), and Nath *et al.* (2009) states that it can be overcome with proper management.

The study was to determine factors that influenced the surface runoff and the availability of soil organic matter in the bamboo-based agroforestry in East Lombok. The research was expected to provide information about the influence of the land productivity in the bamboo-based agroforestry sites in accordance with the land management characteristics of the farmers.

II. MATERIALS AND METHODS

A. Site Description

The research period was from March 2010 to March 2011. It was conducted in the village of Lenek Daya, Aikmel Sub-district, East Lombok District. The village was located in the Menanga watershed and was directly adjacent to the forest of Rinjani National Park. The altitude is 200-400 m above sea level with sloping area. Its soil type was Regosol and it had no technical irrigation (dry land agriculture). The dry land agriculture in the area was dominated by bamboo plantation which was distributed almost evenly throughout the village. Bamboo was commonly planted separated from the agricultural crops.

For generations, farmers have planted crops in combination with bamboo. Planting bamboo is primarily aimed to get an additional income especially from unproductive land. Slope and soil fertility is an important factor for farmers in determining the pattern of planting bamboo in
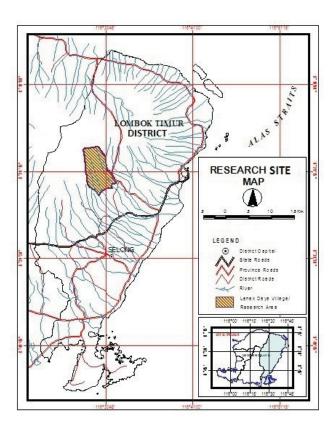

Figure 1. Research site map

combination with crops. Especially on sloping land with low fertility, bamboo canopy closure was dominated. Meanwhile, in more flat and productive land, bamboo canopy rarely closured and was planted as a hedge plant. Cropping pattern of farmers has resulted in land unit management based on similar slopes and bamboo canopy cover. The groups were in accordance with the need of the research (Figure 1).

B. Methods

The study was conducted through: (1) interview; (2) preparation of surface runoff plots; and (3) measurements in the plots, including: surface runoff, bamboo canopy closure, rainfall depth and duration, dissolved sediment, SOM and soil physical and chemical properties.

Twenty three farmers who cultivate bamboo in their agricultural land were interviewed purposively. The main objective of the interview was to obtain information on their land cultivation techniques. Based on the interview, as many as twelve land units were selected and surface runoff plot was placed in each land unit. The surface runoff plots of 4m x 12m (Hudson, 1993) were established on three ranges of slopes that represented the distribution of bamboo-based agroforestry in the area, namely: 0-15°, 30-45° and 45-65°. On each slope, four plots were established, each with bamboo cover of 0-25%, 25-50%, 50-75% and >75%. The numbering of the twelve plots was based on the bamboo canopy cover and the degree of slope, starting from the lowest to the highest, categorized: P0S1, P0S2, P0S3, P1S1, P1S2, P1S3, P2S1, P2S2, P2S3, P3S1, P3S2 and P3S3 (Table 1). Meanwhile, the studied

species of bamboo was bamboo apus (*Gigantochloa apus* Kurz), while the type of soil was Regosol.

Surface runoff measurements were performed in each event of rain during the rainy season (five months of observation). While the dissolved sediment measurements were performed three times at the peak of rainfall and soil characteristics measurements were conducted with three replicates. The laboratory analysis was performed to define the characteristics of soil physical properties and particularly its chemical properties.

Data were analysed through: (1) correlation analysis; (2) multiple linear regression analysis of the three response variables (Y): surface runoff, soil organic matter, and dissolved sediment, including: (a). predictors (X) selection through a stepwise approach (based on the highest value of R-square), (b). regression model testing, including checking for outliers, error and multicollinearity; and (c). estimating regression parameters (β), generalized estimating equation (GEE) (Stokes *et al.*, 2001) was used exclusively for surface runoff; and (3) analysis of variance of surface runoff between plots using Tukey's HSD (Honestly Significant Difference) test at 95% confidence level.

The specified multiple linear regression model (Freund, Wilson and Sa, 2006) is as follow:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + ... + \beta_m x_m + \varepsilon, \quad …………(1)$$

where :

y is the dependent variable (response). x_j, $j = 1, 2, ..., m$, represent m different independent variables (predictors). β_0 is the intercept (value when all the independent variables are 0). β_j, $j = 1, 2, ..., m$, represent the corresponding m regression coefficients. is the random error (usually assumed

Table 1. Plot category

Plot	Bamboo covering Category	Land slope
P0S1	0-25%	0-15°
P0S2	0-25%	30-45°
P0S3	0-25%	45-65°
P1S1	25-50%	0-15°
P1S2	25-50%	30-45°
P1S3	25-50%	45-65°
P2S1	50-75%	0-15°
P2S2	50-75%	30-45°
P2S3	50-75%	45-65°
P3S1	more than 75%	0-15°
P3S2	more than 75%	30-45°
P3S3	more than 75%	45-65°

Table 2. Identification of variables that affect the amount of surface runoff

Variables and the alleged influence of variables on the amount of surface runoff (y_i) from some reference.						Selected Predictors (x_i)
Critchley & Siegert (1991)	Hardjowigeno (2007); Suripin (2001)	Buckman and Brady (1982)	Nath *et al.* (2009)	Divakara *et al.* (2001)	Relf (2009)	
Rainfall Intensity	Measurements were taken at a certain time, only major long rains and rains were known.					1. Rainfall intensity
Rainfall duration						2. Rainfall duration
Slope						3. Slope
	SOM	SOM is very little (3-5% x weight of topsoil)				
Soil	Soil sand fraction					4. Soil sand fraction
	The density of the soil	Heavy soil is a soil composition of the fractions				
			Extensive rooting of bamboo	Extensive root crown area affected		5. Bamboo canopy closure
			Broad canopy of bamboo			
Vegetation				The amount of mulch affected the canopy of bamboo leaves		
			Bamboo leaf mulch	Competition from the canopy and the roots of bamboo plants specify below.	Grass individually suppressed the rate of erosion and runoff.	6. Weight of weeds
Catchment area	Catchment area slope causing different effective plot, this will affect the fit of the rain.					7. Effective plot catchment

to be normally distributed with mean zero and variance σ^2).

Based on Equation 1 and Table 2, which were used to find factors that influence the surface runoff, the basic linear regression equation for surface runoff was set, as follows:

$$y = \beta_O + \beta_1 I\text{-}rain + \beta_2 T\text{-}rain + \beta_3 Slope + \beta_4 L\text{-}closure +$$

$$\beta_5 F\text{-}sand + \beta_6 Weeds + \beta_7 E\text{-}plot + \varepsilon, ...(2)$$

response (y) was surface runoff. β_0 was intercept. β_{1-7} were the corresponding of seven regression coefficients for: rain intensity (I-rain), rain duration (T-rain), slope (Slope), bamboo canopy closure (L-closure), soil sand fraction (F-sand), weight of weeds (Weeds), and effective plot catchment (E-plot) was random error.

The availability of SOM is influenced by its constituent materials and the factors that influence the decomposition process, such as water availability (soil moisture) and soil pH. Meanwhile, the loss of nutrients is associated closely with the surface runoff, SOM availability and soil fertility (Buckman and Brady, 1982). Based on these statements, the basic linear regression equation for the availability of soil organic matter was set, as follows:

$$y = \beta_O + \beta_1 F\text{-}dust + \beta_2 F\text{-}sand + \beta_3 CEC + \beta_4 Ph +$$

$$\beta_5 L\text{-}closure + \varepsilon, ...(3)$$

response (y) was soil organic matter. β_0 was intercept. β_{1-5} were the corresponding of five

regression coefficients for: soil dust fraction (F-dust), soil sand fraction (F-sand), cation exchange capacity (CEC), soil acidity (pH), and bamboo canopy closure (L-closure). was random error.

The basic linear regression equation for soil nutrient loss (indicated by P element loss due to surface runoff) was set, as follows:

$$y = \beta_O + \beta_1 BV + \beta_2 RC + \beta_3 SOM + \varepsilon, \ldots\ldots\ldots(4)$$

response (y) was Phosphorus element loss. β_0 was Intercept. β_{1-3} were the corresponding of three regression coefficients for: soil bulk volume (BV), surface runoff coefficient (RC), and soil organic matter (SOM) was random error.

III. RESULT AND DISCUSSION

A. Surface Runoff and Bamboo Canopy Closure

Table 3 shows hydrological characteristics per research plot. During the study, rainfall occurred as many as 90 times. The depth of the rain was from 1 - 75 mm with an average of 31.8 mm, while the rain duration from 0.3 to 3.7 hours with an average of 1.2 hours. The average runoff coefficient (RC) was 6.3%. Surface runoff ranged from 0.1 to 3.2 mm with an average of 1.8 mm, while the intensity of surface runoff ranged from 0.1 to 2.5 mm/hour with an average of 1.4 mm/hour. Meanwhile, rainfall intensity ranged from 10.8 to 25.4 mm/hour with an average of 20.1 mm/hour.

Using the seven variables in Table 2, the correlation test to the corrected data (without outliers) indicated a high significant correlations (at 99% confidence level) between the intensity of surface runoff with the four variables: rain intensity (I-rain), rain duration (T-rain), bamboo canopy closure (L-closure), and soil sand fraction (F-sand), each of 0.65, 0.30, -0.58, and -0.59 respectively (Table 4).

In line with the results of the correlation test, the result of variable selection in Table 5 and the regression analysis in Table 6 suggested that only four variables make up the surface runoff regression model, namely the intensity of rainfall (I-rain), rain durations (T-rain), bamboo canopy closure (L-closure) and soil sand fraction (F-sand).

As shown in Table 4, there is a high and significant correlation between the slope and the sand fraction (correlation 0.82, significant at the 99% confidence level), and between the two variables (slope and sand fractions) with the intensity of surface runoff (correlation of -0.54 and -0.59 respectively, both significant at 99% significant level). Based on the results of the regression test, the use of soil sand fraction as variable affecting the intensity change of the surface runoff was suitable than use of the slope.

Based on Table 6, it can be concluded that the increase and decrease of rain duration (T-rain) had the greatest influence (the value of the parameter estimates is 0.42) on the increase and decrease the

Table 3. Average hydrological characteristics per plot

Plot	Rain Intensity (mm/hour)	Runoff Volume (liter)	Runoff (mm)	Runoff Intensity (mm/hour)	RC (%)
P0S1	24.9	142.0	3.0	2.5	10.2
P0S2	21.4	107.8	2.7	2.1	9.6
P0S3	16.4	41.6	1.3	0.8	5.0
P1S1	25.3	145.5	3.1	2.5	10.7
P1S2	20.7	123.3	3.2	2.5	12.1
P1S3	10.8	12.2	0.6	0.4	3.2
P2S1	25.0	124.1	2.6	2.0	7.6
P2S2	21.2	116.0	2.9	2.3	10.3
P2S3	17.7	41.0	1.2	0.8	4.6
P3S1	25.4	7.2	0.2	0.1	0.3
P3S2	21.4	5.3	0.1	0.1	0.6
P3S3	10.8	4.3	0.2	0.1	1.1
Average	20.1	72.5	1.8	1.4	6.3

Table 4. Results of the correlation test between the variables on surface runoff

	S-runoff	I-rain	T-rain	L-closure	F-sand	S-lope
	Pearson Correlation Coefficients, N = 653					
	Prob > |r| under H0: Rho=0					
S-runoff	1.0000	0.6519	0.2992	-0.5847	-0.5932	-0.5485
		<0.0001*	<0.0001*	<0.0001*	<0.0001*	<.0001*
I-rain	0.6519	1.0000	0.3350	-0.1752	-0.4504	-0.5042
	<0.0001*		<0.0001*	<0.0001*	<0.0001*	<.0001*
T-rain	0.2992	0.3350	1.0000	0.0233	-0.1327	-0.0701
	<0.0001*	<0.0001*		0.5526	0.0007	0.0736
L-closure	-0.5847	-0.1752	0.0233	1.0000	0.2311	0.3834
	<0.0001*	<0.0001*	0.5526		<0.0001*	<.0001*
F-sand	-0.5932	-0.4504	-0.1327	0.2311	1.0000	0.8176
	<0.0001*	<0.0001*	0.0007	<0.0001*		<.0001*
S-lope	-0.5485	-0.5042	-0.0701	0.3834	0.8176	1.0000
	<.0001*	<.0001*	0.0736	<.0001*	<.0001*	

* Significant at 99% confidence level

Table 5. Variable selection using stepwise selection

Number in Model	R-Square	Variables in Model			
		R-Square Selection Method			
1	0.4249	I-rain			
1	0.3519	F-dust			
1	0.3419	L-closure			
1	0.0895	T-rain			
2	0.6533	I-rain	L-closure		
2	0.5636	F-sand	L-closure		
2	0.5375	I-rain	F-sand		
2	0.4398	T-rain	L-closure		
2	0.4323	I-rain	T-rain		
2	0.4014	T-rain	F-sand		
3	0.7192	I-rain	F-sand	L-closure	
3	0.6698	I-rain	T-rain	L-closure	
3	0.6254	T-rain	F-sand	L-closure	
3	0.5462	I-rain	T-rain	F-sand	
4	0.7362	I-rain	T-rain	F-sand	L-closure

Table 6. Estimated regression parameters (β) of surface runoff using the GEE

Parameter	Estimate	Standard Error	95% Confidence Limits		Z	Pr > |Z|
		Analysis of GEE Parameter Estimates				
		Empirical Standard Error Estimates				
Intercept	5.8266	1.4940	2.8985	8.7548	3.90	<0.0001
I-rain	0.0486	0.0112	0.0266	0.0707	4.33	<0.0001
T-rain	0.4177	0.1050	0.2119	0.6235	3.98	<0.0001
L-closure	-0.0190	0.0042	-0.0273	-0.0108	-4.51	<0.0001
F-sand	-0.0650	0.0209	-0.1060	-0.0241	-3.11	0.0019

intensity of the surface runoff. Meanwhile, the estimated value of canopy closure parameter (L-closure) also showed a significant value (Pr > | Z | < 0.0001) of -0.019. Although its parameter estimate value was the smallest of the observed land characteristics and precipitation, the increase in bamboo canopy closure had significant influence on the decrease of surface runoff by 0.019.

The results of Tukey's HSD test (Table 7) shows the plot grouping based on surface runoff intensity. It appears that plots which have a steep slope (or rather have a high sand fraction) and/or have a high bamboo closure are grouped in the

Table 7. Univariate analysis of runoff intensity data

Tukey Grouping* Variable: Surface runoff intensity				Means	Plot
			A	2.8490	P0S1
	B	A		2.5475	P1S1
		B		2.3178	P0S2
			C	1.5027	P2S1
			C	1.4819	P2S2
			C	1.4805	P1S2
		D		0.4151	P2S3
		D		0.3610	P1S3
		D		0.3584	P0S3
		D		0.0989	P3S3
	D			0.0644	P3S2
		D		0.0376	P3S1

* Means with the same letter are not significantly different

Table 8. Bamboo closure description at each plot

Plot	Bamboo Closure Description			
	Number of Rods	Bamboo Grove Cover (%)	Bamboo Canopy Cover (%)	
			Early	Final
P0S1	0	0	0.0	9.1[*]
P0S2	0	0	0.0	2.5[*]
P0S3	0	0	0.0	13.2[*]
P1S1	19	13	28.0	31.0
P1S2	17	10	28.0	31.8
P1S3	68	16	56.0	65.2
P2S1	52	24	48.0	61.2
P2S2	63	22	48.0	54.1
P2S3	66	23	73.0	80.7
P3S1	65	43	80.0	86.5
P3S2	103	48	64.0	73.1
P3S3	111	46	85.0	88.8

[*] Bamboo canopy shade from outside the plot

group with the lowest surface runoff intensity. These plots are: P2S3, P1S3, P0S3, P3S3, P3S2, and P3S1. These plots have a slope of more than 46° (or rather have sand fraction of more than 72%) and / or bamboo closure of more than 65% as shown in Table 8 and Table 9.

B. Soil Organic Matter, Bamboo Canopy Closure and Regosol Soil Fertility

Table 9 shows the physical and chemical properties of soil at the research plots. The soil organic matter of the plot is medium to very high (3.06 - 6.12%), pH is slightly acidic to neutral (6.16-6.88), phosphorus availability is low to medium (5.26-11.68 ppm), sand fraction is high (66-86%) and the slope is flat to very steep (6-65°). Due to the soil is highly porous (indicated by the high soil sand fraction of more than 60%) and the availability of soil nutrient of Phosphorus is low to medium, the soil fertility remains low. However, the availability of organic matter gives benefits to the soil. Buckman and Brady (1982) states that soil organic matter plays an important role in improving soil structure, providing nutrients for plants and increasing soil water availability.

Based on Table 10, there is no significant individually correlation between SOM with land variables including bamboo canopy closure. But, combined with two other variables: slope and soil dust fraction, it can be seen in Table 11 that the

Table 9. Physical and chemical properties of soil at the research plots

Plot	Slope [4] (°)	F-sand (%)	F-dust (%)	F-clay (%)	SOM [1,3] (%)	C-organic [2] (%)	Bv (gr/cm³)	CEC [2] (cmol/kg)	pH (H₂O) [2]	P₂O₅-Olsen [2] (ppm)
P0S1	13 (GS)	70	28	2	4.14 (H)	2.38 (M)	1.22	19.4 (M)	6.58 (SA)	11.68 (M)
P0S2	33 (S)	78	21	1	3.10 (M)	1.78 (L)	1.20	18.20 (M)	6.80 (N)	7.41 (L)
P0S3	50 (VS)	86	14	0	3.06 (M)	1.76 (L)	1.04	16.20 (L)	6.88 (N)	5.26 (L)
P1S1	7 (F)	66	34	0	6.12 (VH)	3.52 (H)	1.15	19.00 (M)	6.57 (SA)	9.51 (L)
P1S2	36 (VS)	80	19	1	4.12 (H)	2.37 (M)	1.14	20.20 (M)	6.81 (N)	6.97 (L)
P1S3	65 (S)	79	20	1	4.42 (H)	2.54 (M)	1.02	14.60 (L)	6.55 (SA)	6.11 (L)
P2S1	12 (GS)	71	27	2	3.11 (M)	1.79 (L)	1.08	20.60 (M)	6.44 (SA)	10.84 (M)
P2S2	34 (S)	77	23	0	4.75 (VH)	2.73 (M)	1.12	19.00 (M)	6.16 (SA)	6.11 (L)
P2S3	46 (V)	79	19	2	3.38 (M)	1.94 (L)	1.13	17.00 (M)	6.32 (SA)	7.84 (L)
P3S1	6 (F)	72	27	1	4.87 (VH)	2.80 (M)	1.04	25.40 (H)	6.51 (SA)	7.84 (L)
P3S2	33 (S)	81	19	0	3.31 (M)	1.90 (L)	1.11	24.20 (M)	6.52 (SA)	6.98 (L)
P3S3	65 (VS)	81	18	1	6.09 (VH)	3.50 (H)	1.02	26.00 (H)	6.27 (SA)	10.79 (M)

Remarks:
F = Flat, GS = Gently Sloping, S = Steep, VS = Very Steep; L = Low, M = Medium, H= High, VH= Very High; SA = Slightly Acidic, N = Neutral.
[1] SOM = 1.74 x C-organic (Hardjowigeno, 2007);
[2] Categorized according to Sulaeman, Suparto and Eviati (2005);
[3] Categorized according to Bolsa Analytical (2007);
[4] Categorized according to the Decree of the Minister of Agriculture number 837/Kpts/Um/11/1980 and no.: 683/Kpts/Um/8/1981

Table 10. Results of correlation test between the land variable on SOM

	SOM	Slope	F-dust	F-sand	CEC	Ph	L-closure
Pearson Correlation Coefficients. N = 12							
Prob > |r| under H0: Rho=0							
SOM	1.0000	-0.0245	0.4272	-0.3805	0.3630	-0.4019	0.2851
		0.9397	0.1660	0.2223	0.2461	0.1953	0.3690
Slope	-0.0245	1.0000	-0.8231	0.8153	-0.2500	-0.0716	0.2166
	0.9397		0.0010*	0.0012*	0.4332	0.8249	0.4989
F-dust	0.4272	-0.8231	1.0000	-0.9905	0.1288	-0.1785	-0.0945
	0.1660	0.0010*		<0.0001**	0.6899	0.5789	0.7702
F-sand	-0.3805	0.8153	-0.9905	1.0000	-0.1190	0.1919	0.0769
	0.2223	0.0012*	<0.0001**		0.7127	0.5501	0.8123
CEC	0.3630	-0.2500	0.1288	-0.1190	1.0000	-0.3105	0.5054
	0.2461	0.4332	0.6899	0.7127		0.3260	0.0937
Ph	-0.4019	-0.0716	-0.1785	0.1919	-0.3105	1.0000	-0.7057
	0.1953	0.8249	0.5789	0.5501	0.3260		0.0103*
L-closure	0.2851	0.2166	-0.0945	0.0769	0.5054	-0.7057	1.0000
	0.3690	0.4989	0.7702	0.8123	0.0937	0.0103*	

* Significant at 95% confidence level
** Significant at 99% confidence level

CEC has a significant positive relation (parameter estimate is 0.15 and significant at 95% confident level) with SOM. Hardjowigeno (2007) stated that CEC is the soil chemistry that is closely related to soil fertility if the soil is dominated by base cations, Ca, Mg, K, Na (high base saturation) and vice versa if it is dominated by acid cations, Al, H (low base saturation).

Bamboo leaf litter is hard to be degraded. O'Cornor *et al.* (2000) states that most part of bamboo leaves cannot be processed by microbes. Aside from its high value of C/N ratio, the leaves

Table 11. SOM regression parameter estimation using regression test

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
				Parameter Estimates		
Intercept	1	-7.08034	2.42162	-2.92	0.0192	0
Slope	1	0.06512	0.01735	3.75	0.0056	1.23525
F-dust	1	0.27192	0.06332	4.29	0.0026	1.38036
CEC	1	0.15112	0.05766	2.62	0.0306	0.49404

Table 12. Test results in the nutrient content of runoff water

Plot	Ntotal (%)	P_2O_5 (ppm)	K (me/L)	Mn (me/L)	Cu (me/L)	Zn (me/L)	Fe (me/L)
P0S1	0.011	11.21	0.17	0.02	0.01	0.007	0.02
P0S2	0.01	14.57	0.23	0.01	0.01	0.004	0.02
P0S3				not applicable			
P1S1	0.012	31.76	0.27	0.01	0.01	0.006	0.02
P1S2	0.007	42.6	0.22	0.01	0.01	0.003	0.02
P1S3				not applicable			
P2S1	0.004	33.26	0.23	0.01	0.01	0.003	0.02
P2S2	0.027	25.41	0.15	0.01	0.01	0.002	0.02
P2S3	0.008	21.3	0.17	0.01	0.01	0.002	0.02
P3S1				not applicable			
P3S2	0.007	20.55	0.18	0.01	0.01	0.002	0.02
P3S3				not applicable			
Sum	0.075	189.45	1.45	0.07	0.07	0.022	0.14
Average	0.009	23.68	0.18	0.008	0.009	0.003	0.02

Table 13. Parameter estimate of P element loss regression using regression test

Variable	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Standardized Estimate
				Parameter Estimates		
Intercept	1	199.34000	16.11319	12.37	0.0011	0
BV	1	-160.96638	14.67854	-10.97	0.0016	-1.12224
RC	1	0.80395	0.20735	3.88	0.0304	0.39678

of bamboo are also structurally complex which makes it difficult to decompose through a natural mechanical process. As an overview, Singh and Singh (1999) estimates that decomposition of 95% of bamboo leaves takes 28 months. Christanty, Mailly and Kimmins (1996) estimated that the complete decomposition of the leaves of bamboo takes 36 months.

Table 12 displays the test results of the nutrient content of runoff water. Some of the plot did not result in runoff or did result in surface runoff but they did not produce enough runoff to be analyzed in the laboratory at the time of water sampling. As shown in Table 12, the Phosphorus element lost reached on average of 23.68 ppm per plot. The loss of P element affects and suppresses plant growth. The element of P is an essential nutrient. In soil it is available in small quantities, mostly in the form that cannot be easily absorbed by plants and are bound by the Al in acid soils or by Ca in the alkaline soil (Hardjowigeno, 2007).

Based on Table 13 it can be seen that the decrease of soil bulk volume (BV) and the increase of runoff coefficient (RC) significantly increase the nutrient loss (the standardized estimate of regression of the soil density of -

1.122, and the RC of 0.397). Soil with a high density has a low porosity and has the ability to retain the P element better than the porous soil (Hardjowigeno, 2007). Therefore, the decrease of sand fraction helps soil retain the nutrient better so that the loss of nutrients caused by surface runoff can be minimized.

On dry land air with temperature of more than 30°, the standard evapotranspiration (ET_o) is 6-9% (Allen *et al.*, 1998). Without technical irrigation, rain is the only source of water. With the small RC value (6.3%) measured in research plots, the largest soil moisture loss occurs through infiltration (>84%) and only 12.3 to 15.3% is through surface runoff and evapotranspiration. It shows that the highest risk of losing the element P in sandy soil (sand fraction >60%) is through nutrient leaching by infiltration.

Based on these findings it can be indicated that the increase in Regosol soil fertility was determined by an increase in the SOM which was comparable with the increase of CEC, and by the decrease in sand fraction that decreased nutrient loss due to leaching of nutrients. Meanwhile, the influence of bamboo canopy closure on SOM, in relation to soil fertility, remains low due to the decomposition of bamboo leaves litter which is quite long.

IV. CONCLUSION

1. Rainfall intensity, rain duration, bamboo apus (*Gigantochloa apus* Kurz) canopy closure and soil sand fraction were all factors which influenced significantly the intensity of surface runoff. The increase of rainfall intensity and rain duration increased suface runoff, each by 0.049 and 0.412, respectively. Meanwhile, the increase of bamboo canopy closure and soil sand fraction decreased surface runoff, each by -0.019 and -0.065, respectively.

2. The increase in canopy closure of bamboo apus (*Gigantochloa apus* Kurz) showed no significant correlation to SOM, but showed a high correlation with the CEC and soil pH, each of 0.51 and -0.71, respectively. The slope, soil dust fraction and CEC showed significant positive relationship with the SOM, each of 0.065, 0.272 and 0.151, respectively.

3. The improvement of Regosol soil fertility in bamboo-based agroforestry in East Lombok was determined by the increase in SOM through decomposition of bamboo leaves and other organic matters in the long run, and by the prevention of leaching of soil nutrient. The leaching of soil nutrient is through infiltration (>84%) and is only 12.3 15.3% through surface runoff and evapotranspiration.

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