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Full Length Research Paper

Prediction of nitrogen availability based on soil organic carbon in commercial mulberry vegetation of Eastern India

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Appropriate quantification of nitrogen availability in soil is the prerequisite for proper implementation of soil-test based fertilizer-application scheme. However, most of the soil testing laboratories use soil organic carbon level to suggest fertilizer dose for nitrogen; hence, the present study has been initiated to develop prediction equation for estimating available nitrogen content of soil from its organic carbon content to facilitate the implementation of soil test based on nitrogen fertilizer application in mulberry garden. A total of 300 soil samples comprising 100 locations from each of Malda, Murshidabad and Birbhum districts have been analyzed for estimation of organic carbon as well as corresponding available nitrogen content. Analytical data was further subjected to regression analysis and district wise working equations were developed to predict nitrogen availability in soil from its organic carbon content. All the equations registered quite higher R^2 values, significant at 1% level and thus, considered viable to predict nitrogen availability in soil. Moreover, comparison between predicted and observed values of available nitrogen content in some selected soil samples of each of the districts was done to ascertain accuracy of these equations. The accuracy was found reasonable in terms of ±10% variation and thus, the developed equations are competent enough to predict nitrogen availability in soil under mulberry vegetation of the districts under investigation.

Key words: Available nitrogen, mulberry, organic carbon, prediction, soil-test.

INTRODUCTION

Out of the sixteen essential elements, nitrogen plays the key role in the nutrition of plants and mulberry indeed is of no exception in this regard. Improvement in mulberry leaf yield and quality due to application of nitrogen was reported by a number of workers (Pain, 1965; Ray et al., 1973; Kar et al., 1997; Ghosh et al., 2015; Sugiyama et al., 2016). For judicious management, soil test based application of nitrogen fertilizer (Kar et al., 2000) is the most viable approach for the maintenance of mulberry plantation in sustainable mode. The approach is very much quantitative in terms of fertilizer consumption with an added advantage of maintenance of the soil health at

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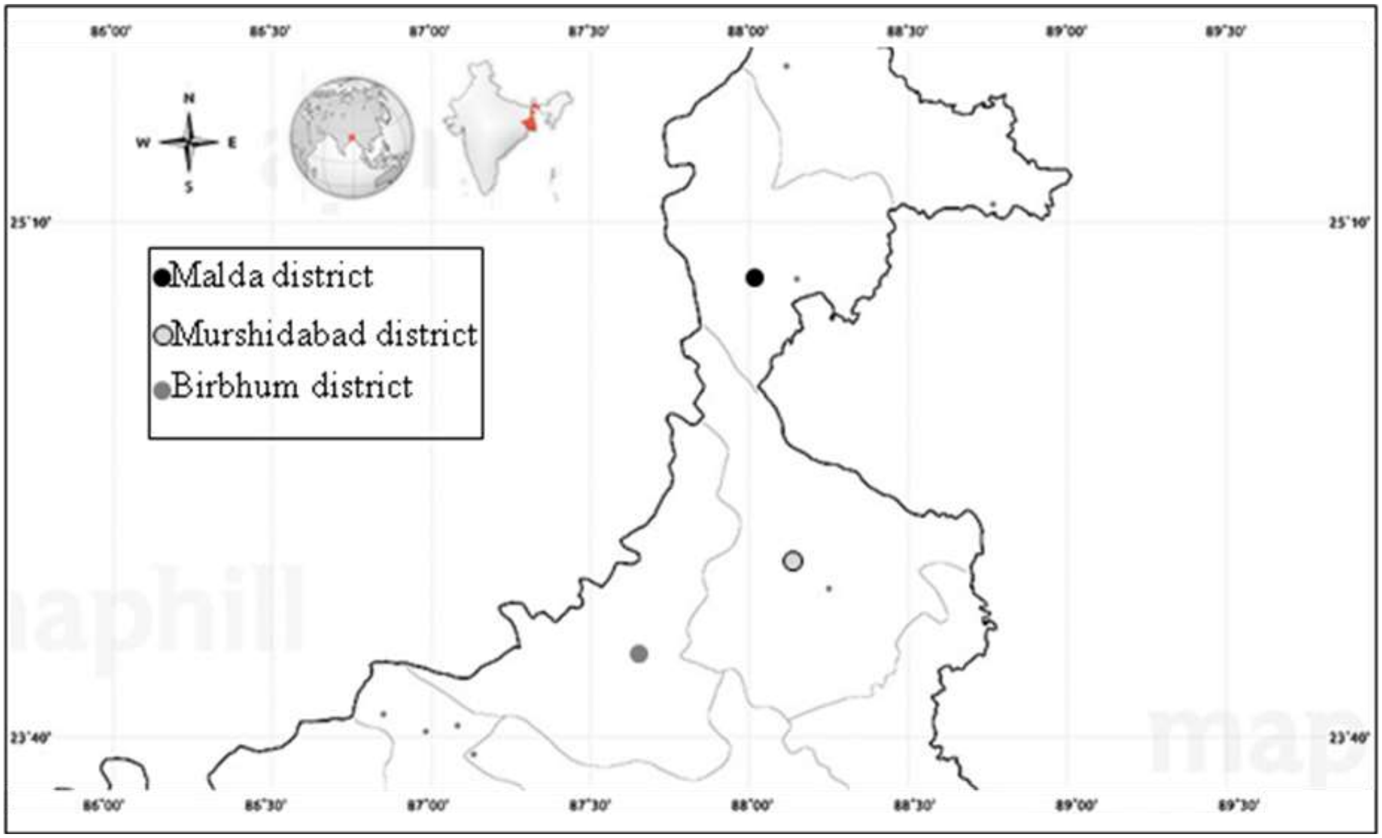

Figure 1. Map of the study site *viz.* Malda, Murshidabad and Birbhum (map redrawn from http://www.maphill.com).

desired level.

Appropriate quantification of nitrogen availability in soil is the prerequisite for proper implementation of soil-test based fertilizer-application scheme. But, most of the soil testing laboratories use soil organic carbon level to suggest fertilizer dose for nitrogen (Dhillon et al., 1999; Rashidi and Seilsepour, 2009; Sanjay et al., 2017). Though mineralization of nitrogen is related to organic carbon content of soil, definite correlation between the latter and available nitrogen content of soil is yet to be explored. Some gross relationship is there in terms of C:N ratio, but, the same predicts range of total nitrogen content of soil and is of no use to soil test based approach for application of nitrogenous fertilizer. Thus, organic carbon based nitrogen fertilizer application is subjected to wide approximation and indeed is semi-quantitative in nature. Particularly, the value of soil available nitrogen is obligatory to work out the nitrogen fertilizer dose through soil test based approach.

In view of the above, the present study was initiated to develop prediction equation for estimating available nitrogen content of soil from its organic carbon content to facilitate the implementation of soil test based nitrogen fertilizer application in mulberry garden. Malda, Murshidabed and Birbhum are the three traditional districts of mulberry sericulture in West Bengal producing major share of commercial cocoons of silkworm in Eastern India. Mulberry growing soils of these districts are distributed over different eco-geographic conditions exhibiting a wide variation in terms of organic carbon as well as available nitrogen content (Kar et al., 2008a). The present study is restricted to these three districts to develop district wise prediction equation for computing nitrogen availability in soil from its organic carbon content.

MATERIALS AND METHODS

Three traditional districts of mulberry sericulture in West Bengal, namely, Malda (25°0'39''N 88°8'27''E), Murshidabad (24°10'33''N 88°16'48''E) and Birbhum (23°50'24''N 87°37'07''E) were considered for the present investigation (Figure 1). Surface soil samples (0 to 30 cm) were collected from the farmers' fields under different seri-villages of these districts. A total of 300 soil samples comprising 100 locations from each of the three districts were collected and subsequently processed for the preparation of composite soil sample (Jackson, 1973). Each of the processed soil samples were further subjected to chemical analysis for estimation of organic carbon and available nitrogen content. Organic carbon contents of the soil samples have been estimated by rapid chromic acid oxidation method (Black, 1965; Kar et al., 2013) while alkaline

Table 1. Comparative study of organic carbon contents of soils under mulberry vegetation of traditional districts of sericulture in West Bengal.

District	Organic carbon content (%)		Percent samples under different classes of organic carbon content		
	Range	Mean	Low	Medium	High
Malda	0.28 - 1.06	0.59 ± 0.014	20	79	1
Murshidabad	0.18 - 1.68	0.47 ± 0.026	76	20	4
Birbhum	0.06 - 1.06	0.41 ± 0.020	71	28	1

Table 2. Comparative study of available nitrogen contents of soils under mulberry vegetation of traditional districts of sericulture in West Bengal.

District	Available nitrogen content (kg ha^{-1})		Percent samples under different classes of available nitrogen content		
	Range	Mean	Low	Medium	High
Malda	128 - 497	292 ± 7.3	32	68	-
Murshidabad	56 - 449	221 ± 10.0	61	39	-
Birbhum	31 - 487	235 ± 11.0	54	46	-

permanganate distillation (Subbiah and Asija, 1956; Kar et al., 2012) was employed for estimation of available nitrogen contents of the corresponding samples.

Data generated from the chemical analysis was subjected to statistical analysis to work out regression equation between available nitrogen content of the soil as the dependent variable (y) and organic carbon content of the same as the independent variable (x). Regression analysis was done district wise and prediction equations relating to available nitrogen content of soil (y) with its organic carbon content (x) were developed separately for each of the districts.

Further, comparison between predicted and observed values of available nitrogen content in some selected soil samples was done to verify the accuracy of prediction equations. The estimated organic carbon contents of the selected soil samples was subjected to the developed regression equations to compute the predicted values of available nitrogen content of the same. Available nitrogen contents of these selected soil samples have also been estimated analytically and termed as observed values and subsequently compared with the predicted values.

RESULTS AND DISCUSSION

Distribution of organic carbon and available nitrogen in the soils under mulberry vegetation of traditional districts of sericulture in West Bengal is presented in Tables 1 and 2, respectively. The organic carbon ranges from 0.28 to 1.06, 0.18 to 1.68 and 0.06 to 1.06% in the soils under mulberry vegetation of Malda, Murshidabad and Birbhum, respectively. On the other hand, available nitrogen ranges from 128 to 497, 56 to 449, 31 to 487 kg ha^{-1} in the soils under mulberry vegetation of Malda, Murshidabad and Birbhum, respectively.

It is interesting to note that none of the soil sample in any of the districts belongs to high category (>500 kg ha^{-1}) of nitrogen availability as per standard rating chart (Muhr et al., 1965). On the contrary, more than 60, 50 and 30% samples of Murshidabad, Birbhum and Malda districts, respectively, are of low category (<250 kg ha^{-1}) of nitrogen availability.

Only 1 to 4% soil samples of these three districts belong to high category (>1.0%) of organic carbon contents and perhaps this is the reason for low-medium level of available nitrogen contents in the soil samples under discussion. More than 70% soil samples of Murshidabad and Birbhum districts belong to low category (<0.5%) of organic carbon contents, while more than 70% soil samples of Malda district belong to medium category (0.5 to 1%) of the same. Thus, it appears that soils of Malda district have an edge over Murshidabad and Birbhum districts in terms of organic carbon as well as available nitrogen contents.

Data pertaining to organic carbon and available nitrogen contents of soils have further been subjected to regression analysis considering available nitrogen content as the dependent variable (y) and organic carbon content as the independent variable (x) as presented in Table 3. As soils under mulberry vegetation of these three districts exhibit wide variation in terms of physiography, parent material, *in situ* weathering and translocation of clay (Kar et al., 2008a), the regression analysis was done district wise. The regression equations for all the three districts register quite higher R^2 values and all are significant at 1% level. Thus, these equations may be considered viable to predict nitrogen availability in soil from the known titer of corresponding organic carbon.

To verify the accuracy, a comparison was made between predicted values of available nitrogen contents of selected soil samples and their corresponding estimated values. The estimated organic carbon contents of the selected soil samples was subjected to regression

Table 3. Regression equations relating to available nitrogen contents (y) with organic carbon contents (x) of soils under mulberry vegetation of traditional districts of sericulture in West Bengal.

District	Regression equation between available N (y) and organic carbon (x)	R^2
Malda	y = 70.94 + 374.44 x	0.53**
Murshidabad	y = 82.49 + 296.84 x	0.58**
Birbhum	y = 59.32 + 425.72 x	0.63**

**Significant at 1% level.

Table 4. Comparison between predicted and observed values of available nitrogen content in some selected soil samples of Malda.

Farmer corresponding to soil sample	Organic carbon (%)	Available N (kg/ha)		Variation (±) % = [(*y*-*x*)/*x*] × 100
		Observed (*x*)	Predicted (*y*)	
Md. Sher Khan, Mothabari, Malda	0.38	233	213	-8.58
Md. Satu Sk., Mothabari, Malda	0.65	289	314	8.65
Sankar Majumder, Bangalgram, Malda	0.36	196	206	5.10
Kartik Majumder, Bangalgram, Malda	0.56	296	281	-5.07

Table 5. Comparison between predicted and observed values of available nitrogen content in some selected soil samples of Murshidabad.

Farmer corresponding to soil sample	Organic carbon (%)	Available N (kg/ ha)		Variation (±) %
		Observed	Predicted	
Samsul Haque, Karjora, Nabagram, Murshidabad	0.71	275	293	6.55
Jasimuddin, Bankipur, Nabagram, Murshidabad	0.49	243	228	-6.17
Chandrasekhar Mandal, Balaspur, Nabagram, Murshidabad	0.60	252	261	3.57
Rezaul Sk., Mallickpur, Khargram, Murshidabad	0.44	196	213	8.67

Table 6. Comparison between predicted and observed values of available nitrogen content in some selected soil samples of Birbhum.

Farmer corresponding to soil sample	Organic carbon (%)	Available N (kg/ ha)		Variation (±) %
		Observed	Predicted	
Adhir Mandal, Akalipur, Birbhum	0.46	240	255	6.25
Paresh Mandal, Bhadrapur, Birbhum	0.50	292	272	-6.85
Sahid Hossain, Bandhkhola, Birbhum	0.47	281	259	-7.83
Prabir Mandal, Barunighata, Birbhum	0.34	191	204	6.81

equations as shown in Table 3 to compute the predicted values of available nitrogen content of the same. Selected soil samples from three different districts were verified under district wise regression equation and results of the same are shown in Tables 4, 5 and 6 for Malda, Murshidabad and Birbhum, respectively.

The tables indicate that the predicted values of nitrogen availability in soil are well in agreement with the corresponding estimated values depicting a variation of -8.58 to 8.65% for Malda, -6.17 to 8.67% for Murshidabad and -7.83 to 6.81% for Birbhum district. Thus, the equations performed well within reasonable accuracy (±10%) (Kar et al., 2008b) and can be used with confidence to predict nitrogen availability in soil under mulberry vegetation of the three traditional districts of sericulture in West Bengal from its organic carbon content.

Conclusion

The developed prediction equations as shown Table 3 are capable of computing nitrogen availability in soil from its organic carbon content with reasonable accuracy. The study promises to solve an analytical problem existing in most of the soil testing laboratories in terms of quantification of soil available nitrogen and the same is certainly one of the efficient tools for the purpose of issuing soil health card to the mulberry growers of this region.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Dried *Azolla pinnata* as a supplementary nitrogen source for lowland rice production in a Calcic Natraquert

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A pot experiment was conducted in the experimental field of the University of Ghana, Legon to examine the effectiveness of dry *Azolla* as N source in flooded rice field. The treatments included incorporating fresh *Azolla* (FA at 90 kg N/ha), dry *Azolla* (DA at 90 kg N/ha), dry *Azolla* + Ammonium sulphate (DA at 45 kg N/ha + AS at 45 kg N/ha), fresh *Azolla* + dry *Azolla* (FA at 45 kg N/ha + DA at 45 kg N/ha), ammonium sulphate (AS at 90 kg N/ha) and a control (C at 0 kgN/ha). The treatments were applied 8 days after transplanting rice. Results showed that the DA + AS treatment, that is, the treatment where dry *Azolla* + ammonium sulphate were used to fertilize the rice had the highest dry weight and total N yield followed by the treatment AS. Total N for the DA + AS treatment was 36.67% over the control whilst that for the AS was 25% over the control. Dry *Azolla* has the potential for supplementing for the nitrogen requirement for irrigated rice.

Key words: *Azolla*, tiller number, total N.

INTRODUCTION

Rice is gaining much research attention owing to an astronomic increase in its consumption relative to lower domestic production in some countries in Africa. The increase in consumption of rice in Africa is related to rapid population growth, incessant urbanization, increased income, and favourable government pricing policies, easy and long storability of rice and ease of cooking. About 90% of the world rice output is produced in Asia (66% in India, Indonesia and China).

Most rice fields in the tropics require the application of nitrogen fertilizer for cost-effective yields (Tilman et al., 2002). Ammonium and amide forms of nitrogen are preferable to nitrate forms in the lowland rice fields because nitrate forms are prone to leaching and losses through denitrification in flooded rice fields. The use of *Azolla* is beneficial in increasing rice production because *Azolla* can supplement more than half of the nitrogen requirements of lowland rice crop. As an aquatic fern, *Azolla* fixes atmospheric nitrogen and makes available some of the fixed nitrogen to the planted rice. *Azolla* can excrete 3 to 4% of the total N fixed to the exterior solution and of the total N released; 15 to 30% was available to the first rice crop (Liu, 1985). Rice field inoculated with *Azolla* before and after transplanting rice resulted in grain

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yields being increased by 54% over the control fields without *Azolla*. The complementary use of *Azolla* and N fertilizer for rice cultivation is receiving attention. Thus, incorporating 5 tons fresh *Azolla*/ha just before planting increased yields of rice by 44% over the control whilst a combination of 30 kg N/ha and 5 tons of *Azolla*/ha increased yields 86.4% (Singh and Singh, 1986). The application of 30 kg N/ha urea in combination with *Azolla* inoculated basally or with the *Azolla* intercropped gave an equal grain yield compared to 60 kg N/ha urea. Plant height, number of effective tillers, dry mass and nitrogen content of rice plants were increased with the use of *Azolla* and N-fertilizers and combinations (Bhuvaneshwari and Singh, 2015).

Azolla also prevents rise in flood water pH, reduce water temperature, curb NH_3 volatilization and suppresses weeds and mosquito proliferation in wetland rice fields (Pabby et al., 2004). When intercropped or incorporated into paddy rice fields, *Azolla* mitigated the rapid loss of nitrogen from chemical fertilizer since the release of the nutrient is progressively slow making it a viable alternative source of nitrogen in lowland rice production (Lumpkin and Plucknett, 1985). The applied *Azolla* increased both total and available nitrogen of the paddy soil. Methane emission was also reduced because *Azolla* improved the content of NO_2^- and NO_3^- in the floodwater and also of the soil. The NO_2^- and NO_3^- oxidized CH_4 to CO_2 (Mujiyo et al., 2016). Organic matter, potassium and the organic nitrogen contents of the soil significantly increased with the use of *Azolla* in rice production (Yadav et al., 2014). Both biochemical and biological properties of the field were improved by *Azolla* incorporation. Thus, the soil urease and phosphatase activities improved and there were increased cellulolytic and urea hydrolyzing activities in addition to significant increase in the population of heterotrophic bacteria due to *Azolla* application (Thanikachalam et al., 1984; Kannaiyan and Subramani, 1992). *Azolla* enhanced the soil biological health and optimized the use of organic, inorganic and biological inputs in an integrated manner (Yadav et al., 2014).

About two thirds of the total nitrogen that was in fresh *Azolla* was mineralized within 6 weeks and the nitrogen was made available to rice plants after the *Azolla* had been incorporated into the soil (Ito and Watanabe, 1984). However, nitrogen mineralization from dried *Azolla* is slower than fresh *Azolla* (Watanabe et al., 1977) when used to grow lowland rice. Dry *Azolla* has been used in feeding livestock and poultry (Giridhar and Rajendran, 2013).

The full potential of *Azolla* as a biofertilizer is yet to be realized since much emphasis has been made on fresh *Azolla* than on dried *Azolla*. Thus, the potential use of fresh *Azolla* in combination with dried *Azolla*, the use of dry *Azolla* and inorganic fertilizer, the combined use of fresh *Azolla*, dry *Azolla* and inorganic N fertilizer have not been fully explored for lowland rice production. This study was carried out to elucidate the use of dried *Azolla* in increasing lowland rice production.

The objective of the study was to examine the effectiveness of dry *Azolla* in influencing lowland rice growth in the Bumbi series (Calcic natraquert).

MATERIALS AND METHODS

Bumbi series is a vertisols of the Accra plains. It lies in a valley with a slope of 0 to 2% and is made up of montmorillonite clay derived from amphibolite and/or hornblende schists with little or no stones in the surface or subsurface horizons. The Bumbi series is deep and very poorly drained thus swelling when wet and very hard and cracks when dry. The Bumbi series has been classified by Amatekpor and Dowuona (1995) as Calcic Natraquert under the USDA Soil Taxonomy System. The soil texture is silty clay loam. The physical and chemical characteristic of the soil is shown in Table 1.

Soil sampling

Soil samples were taken from the plough layer (0 to 20 cm) of the Bumbi series from an uncultivated field at the Irrigation Development Authority (IDA), Ashaiman located on latitude 05° 41.400, and longitude 00°03.018. The area has an annual rainfall between 700 and 1000 mm. All samples were transported to the Department of Soil Science Laboratory of the University of Ghana. The soil was air dried, crashed and passed through a 2-mm sieve to obtain the fine earth fraction that was used for pot experiments later. Part of the fine earth fraction was used for laboratory analysis.

Bulk density was determined using the core sampler method of Blake and Hartge (1965). A core sampler was driven into the soil with a mallet far enough for all of its volume to be filled with the soil while a flat wood plank covered the uppermost opening of the cylinder. The core sampler was then removed by digging around it and then inserted a cutlass just beneath its bottom opening. The core sample was leveled by trimming the excess soil. The sampler was then covered and placed in a polythene bag to prevent water loss. At the laboratory, the soil was transferred into an initially weighed moisture can, reweighed and oven dried at 105°C for 24 h. The bulk density was then calculated.

The pH of the soil was determined using a pH meter with glass-calomel combination in distilled water and 0.01 M $CaCl_2$ solution at a ratio of 1:2 soil: solution. Determination was done in duplicate.

Some of the soil sample was sieved through 0.5 mm sieve and treated with HCl to destroy any calcium carbonate concretions present in the soil. Organic carbon content in that soil sample was determined using the Walkley and Black method (1934) which is based on the reduction of $Cr_2O_7^{2-}$ ion by organic matter, and the unreduced $Cr_2O_7^{2-}$ measured by titration with ammonium ferrous sulphate. The quantity of organic carbon oxidized was obtained from the amount of $Cr_2O_7^{2-}$ reduced. The organic carbon content obtained was adjusted using the factor of 1.32 since the 60 to 86% of soil organic carbon is only oxidized in the Walkley and Black method (1934).

The Kjeldahl method was used in the total nitrogen determination whereby soil (0.1 g) was weighed into Kjeldahl flask and selenium catalyst was added to accelerate the digestion process. This was followed by addition of 5 ml of concentrated H_2SO_4. The mixture was digested until the digest became clear. It was cooled and transferred into a volumetric flask and made to volume. An aliquot of 5 mL was taken into Markham distillation apparatus and 10 mL of 40% NaOH was added. The solution was distilled and the distillate was collected in 2% boric acid (H_3BO_3) solution which was then titrated with 0.01 M HCl from green to purplish endpoint. The

Table 1. Some physical and chemical properties of Bumbi series*.

Properties	Value
Bulk density (Mg/m^3)	1.45
pH	
H_2O (1:2)	7.6
0.01 M $CaCl_2$ (1:1)	7.1
Organic carbon (g/kg)	35.1
Available nitrogen (mg/kg)	410.0
Total nitrogen (g/kg)	1.46
Available phosphorus (mg/kg)	29.4
CEC (cmol/kg)	50.2
Exchangeable bases (cmol/kg)	
Ca^{2+}	12.3
Mg^{2+}	14.5
K^+	0.32
Na^+	0.78

percentage N was then calculated.

The available P was extracted from the soil using the Olsen method. Soil (5 g) was weighed into an extraction bottle and 50 ml of 0.5 M $NaHCO_3$ adjusted to pH 8.5 was added and shook on a mechanical shaker for 30 min. The suspension was filtered through a No.42 Whatman filter paper into a volumetric flask and 5 ml aliquot of the filtrate was transferred into another volumetric flask and the pH was adjusted using P-nitrophenol indicator and neutralized with a few drops of 4 M NH_4OH until the solution turned yellow. The concentration of the available P was determined using the method of Watanabe and Olsen (1965).

Soil (10 g) was weighed in duplicate into an extraction bottle and 100 ml of 1M ammonium acetate solution buffered at pH 7.0 was added. The bottle and its contents was placed on a mechanical shaker and shaken for 1 h. The supernatant was filtered through No.42 Whatman filter paper. The extract was used for the determination of Ca, Mg, Na, and K.

An aliquot (10 ml) of the extract was used for the readings of Ca^{2+} and Mg^{2+} on the Atomic Adsorption Spectrometer (AAS).

The flame photometer was standardized and used to determine the concentration of potassium and sodium in the extract.

Azolla collection, preparation and analysis for total nutrient content

Azolla pinnata was collected from Irrigation Development Authority (Ashiaman, Tema, Ghana). It was gently washed with tap water and dried with tissue paper. The fresh weight, dry weight and total N content of the *Azolla* were determined.

Greenhouse to determine *Azolla* influence on rice growth

Rice seeds (IR841) of 90% germination were nursed in pots and seedlings transplanted later.

Basal phosphorus and potassium were applied to all treatments at the rate of 45 kg P_2O_5/ha and 40 kg K_2O/ha. The experimental design was completely randomized (CRD). The experimental treatments were as follows:

(1) Fresh *Azolla* (FA), 90 kg N ha was applied (that is, 45 kg N/ha FA was basally applied and 45 kg N/ha FA topdressed at booting stage);
(2) Dry *Azolla* (DA) 90 kgN/ha was applied (that is, 45 kgN/ha DA was basally applied and 45 kg N/ha DA topdressed at booting stage);
(3) Ammonium sulphate (AS) 90 kgN/ha (that is, 45 kgN/ha AS was basally applied and 45 kg N/ha AS topdressed at booting stage);
(4) Dry *Azolla* + sulphate of ammonia (DA + AS), 45 kg N/ha DA basal application + 45 kg N/ha AS topdressing;
(5) Dry *Azolla* + Fresh *Azolla* (DA + FA that is, 45 kg N/ha FA basally applied + 45 kg N/ha DA topdressed
(6) Control (C), no *Azolla* nor ammonium sulphate was added to soil sample

Each treatment was replicated three times.

Each pot was filled with 3 kg of 2 mm sieved soil which was then flooded with water and left for a period of time for an equilibrium to be established between the soil and water. Three weeks after transplanting the rice (that is, 21 days), the plant height and tiller numbers were measured and recorded weekly. The plants were harvested 60 days after transplanting by cutting them just above the soil surface. The plants were washed with distilled water and oven-dried at 68°C for analysis. The plant samples were then grinded.

Plant sample analysis

Ground plant material of 0.1 g was weighed into conical flask and 5 ml of concentrated H_2SO_4 was added and left to stand for about 1 h. The mixture was then heated. Hydrogen peroxide was added dropwise until the digest became clear. The digest was cooled and then filtered.

Total N uptake in plant material was determined as follows: A 5 mL aliquot of the digest (described earlier) was taken into a Markhan distillation apparatus. Five millilitres of 40% NaOH solution

Table 2. Height of rice plants in cm of different nitrogen treatments with different sampling times.

Treatment	21 DAT*	28 DAT	35 DAT	42 DAT
AS	20.23	42.6	48.53	54.20
AS + DA	36.13	45.9	49.90	54.27
DA	35.73	45.9	49.43	54.07
DA + FA	31.17	44.6	49.99	55.17
FA	36.13	49.3	53.27	56.83
C	39.77	48.9	50.40	51.93
LSD ≤ (0.05)	7.45	7.71	5.83	5.58

*DAT: Days after transplanting.

was added to the aliquot and the mixture distilled. The distillate was collected in 5 mL of 2% boric acid that contained three drops of a mixed indicator containing methyl red and methylene blue. The distillate was then titrated against 0.01M HCl acid solution (Bremner, 1965). The percentage of nitrogen was then calculated.
The shoot total N (mg/plant) was derived from the shoot biomass (shoot dry matter yield: **SDW**) and the plant N content (% N) as:

$$\text{Shoot Total N } (mg/plant) = SDW\ (g\ /plant) \times \frac{\text{shoot \% N}}{100} \times 1000$$

Statistical analysis

The data on plant height, tiller number, dry weight and Total N were subjected to analysis of variance using Genstat software, 9th edition. The significance of treatment means was tested at the 5% level of probability and the least significant difference (LSD) was used to separate the means.

RESULTS AND DISCUSSION

The Bumbi series has a bulk density of 1.45 Mg/m^3, clay content of 36%. Considering the bulk density, root penetration by most crops in the soil may be inhibited. The soil is slightly alkaline with pH of 7.6 in water and 7.1 in 0.01M $CaCl_2$ (Table 1). The organic carbon content of 35.1 g C/kg could be the consequence of the long fallow period the field was subjected to and the accumulation of organic matter from the sedges growing on the field. Available P content of the soil was 29.4 mg/kg. The exchangeable Ca^{2+} and Mg^{2+} values were 12.3 cmolc/kg and 14 cmolc/kg whilst the Na^+ (0.78 cmolc/kg) and K^+ (0.32) are quite low. The high Ca^{2+} content of the Bumbi series is due to the presence of calcium carbonate concretions.

The height of rice plant increased for all treatments with time (Table 2). In the first week of sampling, the least plant height was recorded by the treatment AS and the highest height by the control, whilst the different treatments (FA, DA, FA + DA, AS + DA) attained almost the same heights with no significance difference among the various heights of the various treatments. For the subsequent weeks, that is, week 2 through to week 4, there was no significant difference among treatments for a particular week. The rice variety IR 841 has been bred to medium height to avoid lodging.

Tiller number increased with time and by the fourth week of sampling, that is, 42 DAT, the highest tiller number was produced by the AS > AS + DA > DA + FA > DA > FA > C (Table 2). The application of ammonium sulphate produced more tillers than any other treatment and the least tiller number was produced by the control. Tiller number ranged from 11 to 30 by the fourth week of sampling. Ammonia sulphate being an inorganic fertilizer released the nitrogen early enough for the plant to use for tiller production as compared to the N released from *Azolla* which is organic N that had to be mineralized to release inorganic forms of N for rice plant to use.

The highest dry weight was observed for the AS + DA treatment followed by the AS treatment and there was no significant difference between them (Table 3). The treatment AS + DA was significantly different from all the other treatments. Even though the dry weight of DA + FA was higher than the individual dry weights of DA and FA, there was no significant difference between dry weight of DA + FA, DA and FA. This shows that the combined use of DA and FA has the potential to increase rice dry matter yield more than the use of dry *Azolla* alone and the use of fresh *Azolla* alone in growing lowland rice. The control had the lowest dry weight. Correlation of 0.879 and 0.853 existed between the dry weight of the rice plant and the tiller number at 35 DAT and 42 DAT implying that tiller number contributed immensely to the dry matter yield of the rice plant in this study.

The AS + DA treatment had the highest total N and this was significantly different from all other treatments (Table 3). The AS treatment had the next highest total N and it was significantly different from DA + FA treatment. The individual treatments of DA and FA had lower total N compared to the combined treatment of DA + FA. Similarly, the treatment AS + DA had higher total N yield than the individual treatments of AS and DA. Combining DA with AS, ensures prolonged N availablility for rice plant use. This is because AS releases N at the initial stage of rice plant growth and at a later stage, DA mineralizes and releases N making that combination a

Table 3. Tiller number, dry matter yield and total N of rice plant of different nitrogen treatments at different sampling times.

Treatment	Tiller number for 21 DAT	Tiller number for 28 DAT	Tiller number for 35 DAT	Tiller number for 42 DAT	Dry matter yield (g)	Total N (mg)
AS	3.67	19.33[c]	27.00[c]	32.00[c]	11.59[bc]	139.1[c]
AS +DA	3.67	14.67[b]	23.00b[c]	26.33[b]	12.83[c]	163.3[d]
DA	6.00	17.00[bc]	21.00[b]	22.67[a]	9.46[ab]	114.8[b]
DA + FA	3.33	14.00[b]	19.00[b]	23.33[ab]	9.53[ab]	124.1[b]
FA	4.00	8.00[a]	14.00[a]	17.33[d]	7.28[a]	98.9[a]
C	5.00	10.33[a]	11.00[a]	12.00[e]	7.52[a]	103.6[a]
LSD ≤ (0.05)	3.24 NS	3.55	4.29	2.9	2.9	13.99

Means with the same letters are significantly not different.

superior treatment to use than DA alone. Similarly, the DA + FA treatment performed better than the DA and FA treatments because the rice plant had available N for the growth of rice over a longer span of time. There was no significant difference in the treatments for total N of DA and DA + FA. The lower total N recorded for the treatment FA as compared to the treatment DA is difficult to explain because one would have expected higher total N yield from the fresh *Azolla* than the dried *Azolla* since dried *Azolla* mineralizes and releases N more slowly (Ito and Watanabe, 1984) than fresh *Azolla* and that can retard the vegetative growth of rice plant.

Conclusion

The application of dried *Azolla* and ammonium sulphate performed better in all the parameters examined than the other treatments. Thus, dry *Azolla* can be used to supplement the nitrogen fertilizer supplement of lowland rice. Also, the full potential of *Azolla* can be realized when both fresh and dried forms of *Azolla* are considered for rice and other crop production.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Soil erosion magnitude of upland farming practices in Bataan

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There are factors affecting erosion such as climate, soil type, vegetation and topography. Upland areas are denuding exponentially due to the fact that those people looking for livelihood had little concern and awareness on environmental sustainability and management. Upland farming practices that are easy like weeding, pest control and fertilization were often carried out without soil erosion control and water management. The result of the study revealed that an area with intercropped permanent crops has less amount of soil eroded or tolerable annual soil loss. But the areas with short duration crops (cash crops) and which adopted the same cropping pattern from the previous season resulted to severe soil erosion. Calculated annual soil erosion are 3.33, 4.57, 23.18, 0.31 tons and zero erosion for Site 1, Site 2, Site 3, Site 4, and Site 5, respectively.

Key words: Intercrop, severe erosion, tolerable erosion, Bataan Philippines.

INTRODUCTION

Soil erosion caused by rainfall result application of energy from two distinct sources, namely (a) the falling raindrops and (b) the surface flow. The energy of falling raindrop is applied slantingly or vertically from above, whereas the surface flow is applied more or less horizontally along the surface of the ground. The chief role of the falling raindrop is to detach soil particles, whereas that surface flow (outside the rills and gullies) is to transport the soil. The falling raindrop also makes a major contribution to the movement of the soil on unprotected sloping lands during the periods of heavy impact storms, by splashing large quantities downslope and by imparting transporting capacity to the surface water by keeping it turbid.

The amount of erosion in one site depends on the range of factors including steepness of slope, soil type, percentage and type of vegetation which covers the area, slope length, amount of rainfall, soil moisture levels prior to specific rainfall events, and condition of soil surface.

Major interest would be to compare the amount of soil erosion at different farming system in the upland of different crops at a given rainfall and to find out if this is more beneficial to farmers.

The study generally aims to determine the magnitude of soil erosion in upland areas of Bataan directly from the

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field where different cultivation practices and crop production are employed specifically: to determine the magnitude of soil eroded at specific area, slope, slope length and vegetation; to determine the farming practices and cropping pattern used in the upland areas of Bataan, and to determine the prevalent problems and advantages encountered on specific practice.

RELATED LITERATURE

The total splash (sum of up, down and across) increased with slope, indicating that splash detachment increased as the slope increased (Grosh and Jarret, 1994). This was likely due to the kinetic energy of rebounding splash droplets at the steeper slopes. More than 99% of the splash soil moved downslope at the 85% slope. Net downslope splash increased at a second order polynomial rate relative to slope.

Kinnell (1990) stated that it is possible to examine the effects of rain, flow and particle characteristics on the movement of soil material from a surface eroded by shallow rain-impacted flows that are incapable of entraining soil particles without the aid of raindrop impact.

According to Agarwal and Dickinson (1991) that unit sediment transport capacity has been observed to be influenced by the unit discharge, flume slope, and median particle diameter of soil. The exponent of the power relationship between unit sediment transport capacity and flume slope appear to vary with the median particle diameter.

The power relationship was also used to relate unit sediment transport capacity to median particle diameter of the input as well as the transport soil. The median particle diameter of transported soil, as well as of input soil, influenced the exponents of the power relationship between unit sediment transport capacity, flume slope, and unit discharge. Sediment transport capacity in overland interrill flow can be represented with the variables unit discharge, flume slope, and median particle diameter of soil.

The conservation bench terrace (CBT) system has been found effective in reducing runoff and soil loss by over 80 and 90%, respectively, as compared to the conventional system (Sharda et al., 2002). The CBT system registered 7.4% of rainfall as runoff and 1.19 Mg ha^{-1} of soil loss as compared to 36.3% and 10.1 Mg ha^{-1} in the conventional system of sloping borders.

As stated by Gilley et al. (1990) that for most of the soil, the total runoff amount during the wet simulation run was similar. However, significant differences in soil loss were found between sites. Thus, substantial variations in soil erodibility existed between many of the study locations.

Ho et al. (2004) stated that the increasing rainfall may accelerate water erosion in watersheds and raise the probability of flooding events in the urban areas. The impacts include environmental and social-economic conditions.

METHODOLOGY

The study area

Bataan province of Region III is a peninsula of around 80.9% upland areas. These areas are suited for tropical crops like pineapple and orchard crops. The valleys and hilltops cover about 63,000 hectares of varying slopes ranging from 2% or less than 8%. On the other hand, the lowland areas are devoted to lowland-based crop for additional production of the province. Bataan has two distinct seasons: the rainy and dry season. The rainy season starts around May and ends sometime October. The rest of the year is dry with occasional rains dispersed widely throughout the province. Typhoons visit the area especially during the months of June to September. Floods occur annually in lowland areas due to heavy rains and clogging of heavily silted outlets to Manila Bay attributed to severe erosion in the uplands.

The prevailing climatic condition is categorized under Type I. The average rainfall is 3,934 mm with an average of 133 rainy days a year. The annual mean temperature is at 27°C with May as the warmest month. The mean annual relative humidity is 79% which the highest in August at 87%.

Upland farming systems are prepared using carabao drawn plow after clearing shrubs, weeds and stumps. However, steep slopes have to be hoed since plowing is difficult. Planting along the slopes start from the highest part to the lower part of the field.

Contour lines are established as a basis of making furrows. The planting is done across the slope following the established contour lines are reference in establishing hill and row spacing.

The continued removal of plant cover and cultivation of the soil is one serious threat to the environment for these could accelerate erosion. Severe erosion lowers land fertility and eroded soil carried by runoff settles in drainage outlets resulting to floods.

Materials used

The use of survey materials such as bond papers, printer ink (refill), folders and envelops. At the field experiment, 70 L capacity drum, PE pipes, graduated stakes, digital weigher, transparent plastic bag, ruler, pad paper, ballpens, pencils and indigenous materials are used such as buho and madre cacao.

Vegetation in the experimental area was identified such as cogon, kalmot pusa, vetiver, carabao grass and other common grasses or weeds. Identified trees were madre cacao, hawili (tibig) and mahogany. Crops produce and established plantation by the farmers include pomelo, rambutan, banana, papaya, coconut, coffee, citrus, ube, ginger, pineapple, mango, calamansi and sweet potato.

The location of the experimental area is at hilly land, with the soil type of Antipolo clay (BSWM, 2003, Soil Survey Report, Bataan Province), and the soil slope or gradient ranges from 9 to 18° (15.83 to 32.49%) to determine the degree or amount of soil sediments eroded. Sites were select according to crops planted and farming practices. There were five sites selected accordingly (Figures 1 and 2).

The three sites were located at Bataan Peninsula State University (BPSU) Abucay campus where different vegetation and crops were grown in the area because of different slopes.

Preparation of the experimental area

Along the ranges of percent slope, gradient will be initially evaluated to attain the ease of gathering data. Experiments are laid out and established instrumentation like aliquots such as drum, established calibrated stakes and indigenous materials to ensure the gathering of samples. Every plot has to be established with

Figure 1. Location of on-site experiment.

Figure 2. Location of off-site experiment.

Table 1. Vegetation identified and calibrated stake reading from site 1.

1.2 m × 44.70 m 14° slope	Calibrated stake reading (cm)						
Vegetation	**Stake #**	**4/28/09**	**6/20/09**	**8/15/09**	**9/19/09**	**10/13/09**	**1/25/10**
1. Kalmot Pusa	1	25.5	25.0	25.0	24.5	25.0	R - 30.0
2. Cogon	2	24.5	23.5	24.0	24.5	24.0	23.5
3. Guava	3	23.5	23.5	24.0	23.5	24.0	24.0
4. Madre Cacao	4	23.0	22.5	22.5	22.5	22.5	22.5
5. Pomelo	5	-	20.5	20.5	20.0	19.5	20.0
6. Rambutan	6	-	21.0	21.0	20.5	20.5	20.5
7. Banana (lakatan)	7	-	23.5	23.5	23.5	24.0	23.5
8. Papaya	8	-	25.0	25.0	25.0	24.5	R - 19.5
9. Coconut	-	-	-	-	-	-	-
10. Vetiver	-	-	-	-	-	-	-
11. Grasses	-	-	-	-	-	-	-

instruments monitoring the soil erosion at specific gradient, farming practices and cropping pattern.

To analyze and evaluate results accurately and present the results of known measures of different variables, the sets of data were monitored and gathered. Data gathering was done on weekly basis to monitor the differences from the previous data and to find alternative solutions if problems rises during the study period.

Rainfall

Following the standard time for gathering agro-meteorological data, rainfall depth will be collected and measured at the established agro-meteorological station of BPSU. Rainfall intensity is also monitor during 8 AM and 2 PM of the day.

Depth of soil sediments

Depth of soil sediments eroded at certain area is monitored using the graduated stakes established. Gathering of data will be regular especially during the rainy season to gather efficient and reliable data for the analysis.

Vegetation

Grown grasses, weeds and trees are also monitored which also affected the amount of soil eroded at a given rainfall intensity.

Crop parameters

Crop parameters are also observed as a basis of reasoning such as the height, fruit diameters, weight of harvested crops, etc., and will also be observed to monitor the differences between such systems of planting, practices and cropping pattern.

The descriptive survey method of gathering data will be the research technique used in the analysis of farming practices and cropping pattern. Randomized Completely Block Design (RCBD) will be used in the analysis of data gathered to come up with reliable result of the experiment. Least Significant Mean Difference (LSMD) Test will also be used to evaluate the variations among treatment means. Experimental treatments will layout and randomly be distributed using the standard procedures of randomization and layout design.

RESULTS and DISCUSSION

Table 1 shows that there were eleven grass species found in the experimental site. The soil weight loss measured was 3,331 g (621.0 kg/ha) during the study. The R denotes the replacement of the calibrated stakes (erosion pin) lost or destroyed because of human activities. During the reading of calibrated stake, the measure was changed initially to reduce the fall, indicating the soil detachment, transport or soil erosion. Experimental site was comparable with other site due to its vegetation density.

Table 2 shows that the calibrated stake reading reduces showing the soil movement caused by the rainfall variation (Figure 3). The total soil weight loss measured was 4,569 g (1,487.3 kg/ha) during the study period. The established crops at the experimental site were permanent intercrop of banana, coffee and coconut, and they were productive.

Table 3 shows the minimal number and the density of vegetation grown as compared to other sites. The soil weight loss measured from this experimental site was 23,185 g (8,118.0 kg/ha), which is severe erosion happened in the site. The calibrated stake reading reduces continuously till the end of the study period. The strip cropping could not resist the soil erosion caused by water.

Table 4 shows the area was steep as compared to other site and productive. The number and density of vegetation also affects the amount of soil eroded in the area. As support basis using the calibrated stakes, there was a slight difference in readings prior to the establishment continuously. The soil weight loss is 311 g (34.56 kg/ha) during the study period. Crops were

Table 2. Vegetation identified and calibrated stake reading from site 2.

1.2 m × 25.6 m 16° Slope		Calibrated stake reading (cm)					
Vegetation	**Stake #**	**4/29/09**	**6/20/09**	**8/15/09**	**9/19/09**	**10/13/09**	**1/25/10**
1. Banana	1	25.5	25.0	25.0	26.0	25.5	25.0
2. Coffee	2	26.0	25.0	24.0	23.5	23.0	23.0
3. Coconut	3	27.0	26.5	26.5	26.5	26.5	26.5
4. Madre Cacao	4	26.0	26.0	26.0	25.5	25.5	25.5
5. Carabao grass	5	29.0	29.0	28.5	29.5	29.5	29.0
6. Hawili (tibig)	6	27.0	26.0	25.5	25.0	24.5	24.5
7. Citrus	7	25.0	lost	-	19.0	19.0	19.0
8. Antipolo (60 cm dia)	8	25.0	25.0	25.0	24.0	24.5	24.0
9. Grasses							

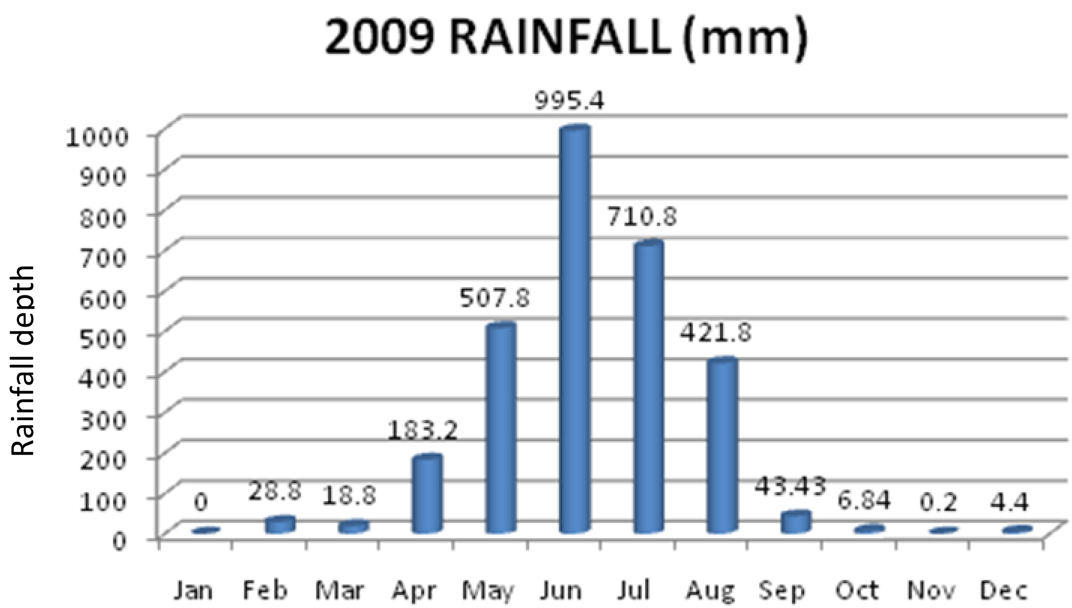

Figure 3. Rainfall depth (mm) for the study period.
Source: BPSU-BSWM AWS Abucay. Total RF=2921.5 mm

Table 3. Vegetation identified and calibrated stake reading from site 3.

1.2 m × 23.8 m 9° Slope		Calibrated stake reading (cm)					
Vegetation	**Stake #**	**5/14/09**	**6/20/09**	**7/24/09**	**9/19/09**	**10/13/09**	**1/25/10**
1. Ube	1	26.5	26.5	26.5	26.0	26.0	24.0
2. Ginger	2	23.5	23.5	23.5	22.5	22.5	22.5
3. Madre Cacao	3	24.0	23.5	23.5	22.0	22.0	22.0
4. Pineapple	4	26.5	24.0	24.0	28.0	28.0	27.5
5. Grasses	5	27.5	27.0	27.0	27.0	27.0	27.0
-	6	27.0	27.0	27.5	27.5	27.5	27.0
-	7	30.0	31.0	32.0	33.0	32.5	32.0
-	8	25.5	28.0	29.0	28.0	28.0	27.5

Table 4. Vegetation identified and calibrated stake reading from site 4.

1.2 m × 75.0 m 18° Slope	Calibrated stake reading (cm)							
Vegetation	**Stake #**	**4/16/09**	**6/11/09**	**7/9/09**	**10/8/09**	**11/27/09**	**1/27/10**	**5/28/10**
1. Pineapple	1	35.5	35.0	36.5	36.5	36.0	36.0	36.0
2. Coconut	2	23.0	23.0	22.0	22.0	22.0	22.0	22.0
3. Mango	3	29.0	29.5	29.5	29.0	29.0	29.0	29.5
4. Calamansi	4	20.0	19.0	19.5	20.0	20.5	20.5	20.5
5. Mahogany	9	-	20.0	17.5	17.5	17.5	17.5	18.0
6. Banana	10	-	21.0	16.5	16.5	16.0	16.5	17.0
7. Madre Cacao	-	-	-	-	-	-	-	-
8. Cogon	-	-	-	-	-	-	-	-
9. Grasses	-	-	-	-	-	-	-	-

Table 5. Vegetation identified and calibrated stake reading from site 5.

1.2 m ×12.5 m 18° Slope	Calibrated stake reading (cm)							
Vegetation	**Stake #**	**4/16/09**	**6/11/09**	**7/9/09**	**10/8/09**	**11/27/09**	**1/27/10**	**5/28/10**
1. Sweet Potato	5	28.0	27.5	27.5	27.5	28.0	27.5	-
2. Cogon	6	21.0	21.0	21.0	21	-	-	-
3. Mohogany	7	28.5	28.0	28.0	28.5	28.5	28.0	28.5
4. Grasses	8	23.5	23.5	23.5	24.0	24.0	24.0	23.5
-	11	-	25.0	24.0	24.5	24.5	24.5	24.5
-	12	-	20.0	19.5	19.5	20.0	20.0	19.5

planted in contour wherein the major crop is pineapple, and the permanent crops are coconut, mango and calamansi.

Table 5 is the same steepness with Site 4, 12.5 m slope length and the area was thickly dense with cogon. The only crop produced was sweet potato in strip of 3 m. There was no loss of soil in the area.

Figure 3 graph shows the monthly rainfall for the year 2009. It presents that during the months of May, June, July and August, it has deepest rainfall and more number of rainy days. The total rainfall depth for the year 2009 was 2921.5 mm, during the study period. Those months mainly affects the calibrated stake reading and the total wFeight of soil measured in every experimental site that has erosion observed.

Conclusions

At different slope, length of slope, vegetation and land use affect the erosion magnitude for specific sloping land. The activities regarding farm and crop improvement such as land preparations, weeding, cropping pattern and calendar are also considered in soil and water management of upland areas and affects the amount of soil eroded per year.

Site 1 was selected because of the long term or permanent intercrops established like rambutan (*Nephelium lappaceum*), pomelo (*Citrus maxima*), coconut (*Cocos nucifera*), coffee (Coffea) and banana (Musa). Even site 2 has long term intercrops under more steep slope and undisturbed soil. Site 3 has the highest soil erosion magnitude due to its seasonal crops production or cropping pattern done. Offsite 4 had soil erosion of 311 g as compared to zero of offsite 5 because of alley cropping made in offsite 5 and the strip was planted with pineapple with cogon grown.

Sites 1, 2 and 4 follow the intercropping of permanent crops. Also, established vegetation across the slope such as vetiver (*Chrysopogon zizanioides*), cogon (*Imperata cylindrical*), common grasses and even permanent crops reduce the soil erosion or soil movement downstream.

RECOMMENDATIONS

To manage soil erosion in the upland, intercropping of permanent crops across the slope, land use, planting system, selection of proper crops for the area and strip cropping must be established. Permanent productive crops should be established and intercrop with cash crops using zero tillage if possible to maximize the area in the sloping areas.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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