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Effect of Slope Gradient on the Selected Soil Physico-Chemical Properties in Arecanut Plantation of KolasibDistrict, Mizoram.

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ABSTRACT

The present study was carried out to investigate the effect of slope gradient on physico-chemical properties of soil and to provide the basic information about its fertility status under Arecanut Plantation in Kolasib District of Mizoram, North-East India. Soil samples were collected from three slope gradients, namely, gentle slope (0-15%), moderate slope (15-30%) and steep slope (>30 %) in four replications. The collected samples were air dried, sieved and analyzed for various soil fertility parameters such as bulk density, pH, organic carbon, primary nutrients (N, P, K) and secondary nutrients (Ca, Mg, S). Results revealed that soil reaction in the study area varied from strongly acidic to moderately acidic with pH values ranged from 5.07, 5.33 and 5.64 along the slope gradients. The data on various parameters were categorized into low, medium and high classes based on soil fertility ratings and nutrient index was calculated. Soil fertility in the studied area was high with respect to nitrogen and medium in all others. However, the detrimental effects of slope gradient are higher at steep slope as compared to gently slope areas. All the soil properties were significantly affected by slope gradient except for soil porosity and available potassium. Therefore, there is a need to restore and sustain the nutrient balance along the different slope gradients by adopting proper management like application of Farm Yard Manure (FYM) and green manures at regular intervals and balanced intercropping etc.

KEYWORDS: soil properties, slope gradient, effect, soil nutrient and fertility, Mizoram.

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INTRODUCTION

The Arecanutpalm (*Areca catechu* Linn.) belonging to family Arecaceae is a traditionally important commercial crop in India. The economic produce is the fruit called ‘betel nut’ or ‘supari’ and is used mainly for masticatory as well as value added products. It plays a prominent role in the religious, social and cultural functions and economic life of people in India[1]. It is predominantly grown in humid tropics of West coast and North-East regions of India namely Karnataka ranks first with an area of 23,60,000 ha, Kerala ranks second with an area of 8,80,000 ha, Assam ranks third with an area of 7,33,000 ha, Meghalaya ranks fourth with an area of 11.2'000 ha, West Bengal ranks fifth with an area of 9.3'000 ha, Tamil Nadu ranks sixth with an area of 4.8'000 ha, Andaman and Nicobar Islands ranks seventh with an area of 4.4'000 ha, Tripura ranks eight with an area of 3.4,000 ha, Maharashtra ranks ninth with an area of 2.2,000 ha, Goa ranks tenth with an area of 16,000 ha, Mizoram ranks eleventh with an area of 13,000 ha, Andhra Pradesh ranks twelfth with an area of 0.1'000 ha and Pondicherry ranks thirteenth with an area of 0.3,000 ha respectively[2]. India is the largest producer and consumer of arecanut. The total production of arecanut in India is 1, 38, 50,000 million ton with an area of 51, 00,000 ha with productivity of 224.1 kg per ha[3].

Arecanut has been cultivated as a cash crop inthe state of Mizoram for quite a long time. Adoptions of such economically high valued tree plantations to these areas where agriculture is the mainstay for about 60% of the population andcharacterized by high dependence on rainfall has come as an opportunity for the farmers who typically practiced shifting cultivation a chance to enhance and diversify their livelihood. Owing to its tropical location, undulant hilly ranges and its moderate climate the area under arecanut cultivation has doubled in Mizoram from 5,010 ha in 2011-12 to 10,740 ha in 2014-15, but with a decline in the production from 12,390 ton to 7,270 ton[2-4]. Continuous cultivationof these plantation cropson the same land results in soil fertility depletion. For optimum arecanut production soil properties play a dominant role in addition to climatic conditions and water resourcesfacilities[5]. In the study area, cultivation on steep slopes is the dominant factor for runoff and erosion that adversely affect the soil physico-chemical properties and crop productivity. Thus, there is a need to restore and sustainthe nutrient balancealong the different slope gradients. This study aimed to investigate the effect of slope gradient on selected soil physico-chemical properties and to provide the basic information about the fertility status ofArecanut Plantation soils.The present study will be the first of its kind to be undertaken in the state of Mizoram, North-East India (Indo-Burman Hotspot region).

MATERIAL AND METHODS

Study Area

Mizoram is one of the eight state of the North-East India, situated in the extreme end of the Himalayan range covering a total area of 21,087km^{2}within altitude ranging from 500 m to 2157m. Kolasib is an important and potential district ofMizoram for agriculture production. The total geographical area of Kolasib district is 1382.51 km^2, which is about 6.56% of the state area. It is situated between 23˚5’ and 24˚35’ N Latitude and 92˚3’ W– 93˚E Longitude. It comes under the tropical monsoon climate zone and experiences direct impact of monsoon. The average rainfall is 2703 mm per annum. The average temperature ranges between 11° C - 34° C with relative humidityvaries from 69% - 80%[6].

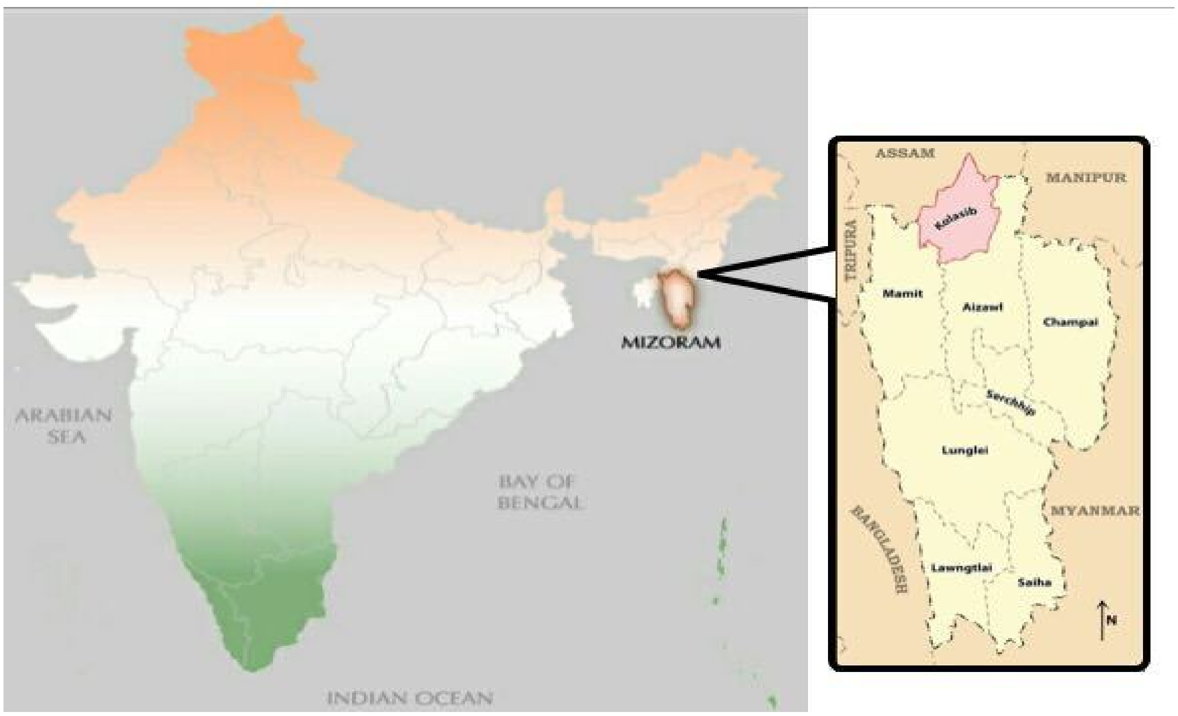

Fig1: Map of Kolasib District of Mizoram, showing study area

Sample collection and analysis

Soil samples were collected from three different classes of slope gradient: gentle slope (0-15%), moderate slope (15-30%) and steep slope (>30%) gradients from two subsequent depths (i.e. 0- 20 cm and 20-40 cm). The soil samples were air dried, grind and screened using a 2 mm sieve. The processed soil samples were analyzed for bulk density and soil pH[7], organic carbon[8], total nitrogen[9], available phosphorus[10], potassium ions by flame photometer, calcium and magnesium by EDTA titration[11] and sulfur ions by spectrophotometer[12].

Data analysis

Statistical comparisons of soils under different slope gradient were performed by one way analysis of variance (ANOVA) at 0.05 significance level. All data were analyzed using MS excel and SPSS (v. 16.0) software.

RESULTS AND DISCUSSION

Physical properties of soils

The data on table2 revealed that effect of slope gradient on soil bulk density (BD) was significant ($p<0.05$). BD was recorded the lowest on the gentle slope area (1.25 g/cm^3) andhighest on the steep slope area (1.31 g/cm^3) (Table 1).The higher value of soil BD maybe due to low clay and high sand content as well as low amount of organic carbon[13].Soils BD under the study area were found to be less than 1.6 g/cm^3, which indicates that the soils are not compacted[14]. Soil porosity is the ratio of the volume of soil pores to the total soil volume. The bulk density of a soil is inversely related to the porosity[15]. Prior to which the lowest total porosity (50.69%) was recorded on steep slope area, while the highest total porosity (52.66%) was recorded on gentle slope area (Table1).

Chemical properties of the studies soils

Soil pH varied significantly under the effect of slope gradients ($p< 0.01$) (Table2). The value of soil pH ranged from 5.07, 5.33 and 5.64 along the slope gradients (Table1). The pH reaction of the studied soils is attributed to the acidic nature of the parent rock coupled intensive leaching of bases. Soil organic carbon (OC) is the carbon (C) stored in soil organic matter (OM). OM is a heterogeneous, dynamic substance that varies in particle size, C content, decomposition rate, and turnover time[16]. OM is different to OC in that it includes all the elements (hydrogen, oxygen, nitrogen, etc) that are components of organic compounds, not just carbon[15]. Organic matter (OM) content of the soil was rated medium (< 2%)[17]. There is a statistically significant effect ($p<0.05$) of slope gradient on both OC and OM (Table2). The lowest OC (1.72%) and OM (2.96%) was recorded in soils of the steep slope area, whereas the highest OC (2.14%) and OM (3.69%) was recorded in soils of the gentle slope area respectively (Table1). However, the difference in OC and OM content along the slope gradients may be attributed to insufficient canopy cover to suppress runoff from steep slope which resulted in loss of plant nutrient and deposition of organic materials in the gentle slope that resulted in better biomass production and moisture storage.

Total Nitrogen (TN) is the sum of nitrate (NO3), nitrite (NO2), organic nitrogen and ammonia. Similar with OM, TN was significantly affected ($P<0.05$) by slope gradient (Table2). The lowest (1.55%) and highest (2.95%) total nitrogen were recorded in steep and gentle slopes respectively (Table1). The unexpected high content of total nitrogen was attributed to low mineralization of the organic matter. This is supported by high, positive and significant correlation with OM (r= 0.71**) (Table 3). The high amount of TN in the soils helps to improve soil quality which in the long-run encourages plant growth and agricultural productivity and sustainability[18-19].

Phosphorus (P) plays an important role in energy transformations and metabolic processes in plants[20]. The levels of available P were lowest in (10.33 kg/ha) steep slope and highest (16.38 kg/ha) in gentle slope areas (Table1). P in soil is unavailable to plants because they are highly insoluble. Plant uptake, erosion, leaching and fixation can be accounted for lower amount of P in all the soils[21]. The Pearson's result (Table3) indicates that OM (r= -0.36**) and TN (r= -0.57**) had negative but significant relation with P while it showed significantly positive correlation with pH (r = 0.51**). Potassium (K) is one of the three major nutrients after N and P required for the build-up of biomass in plants. Differences of slope gradient among the areas did not significantly ($P>0.05$) affect available K. In addition to which OM (r= -0.39) and TN (r= -0.48) is found to have negative and significant relation with K (Table3). The value of K in the studied soils varied between 95.5 kg/ha and 274.55 kg/ha (Table1) and were rated low to medium according to Methods Manual of Soil Testing in India[22]. Less use of FYM, no addition of chemical fertilizers and poor recycling of nutrients from litter residues may also have resulted in low K content[21]. The lowest values of available K were recorded for moderate slope and almost similar values were recorded in gentle and steep slopes. Secondary nutrients (Ca, Mg and S) are nutrients that slightly limit crop growth and are moderately required by plants. All the studied secondary nutrients were significantly ($p<0.05$) affected by slope gradient (Table2). Magnesium (Mg) and Sulfur (S) showed similar pattern of variation along the slope gradients, found to be lowest in steep slope and highest in moderate slope areas (Table1). The Pearson's result further depicts a positive and insignificant relation between Mg and S (r= 0.11). In Table3 showed negative and significant relation between Mg with TN (r= -0.54**) whereas S had high, positive relation with OM (r= 0.58**). Calcium (Ca) was recorded to be lowest (3.47 mg/kg) in the sleep slope and highest (4.20 mg/kg) in moderate slope areas (Table1). The output of the correlation matrix revealed that Ca and Mg have high, positive and significant (r= 62**) correlation. It also share positive and significant association with soil porosity (r= 0.26*), P (r= 0.54**, r=0.58**) and K (r= 0.41**, r= 0.46**). However, these variations among the secondary nutrients may be due to differences in parent material and losses due to erosion.

Table 1: Summary of the descriptive statistics for selected soil physico-chemical properties.

Soil Properties	Slope Gradients (%)	Mean	Std. Deviation	Std. Error	CV (%)	Min	Max
Bulk density (g/cm^3)	Steep (>30%)	1.31	0.06	0.01	4.91	1.13	1.41
	Moderate (15-30%)	1.29	0.1	0.02	7.52	1.06	1.51
	Gentle (0-15%)	1.25	0.08	0.02	6.74	1.13	1.54
Porosity (%)	Steep (>30%)	50.69	5.45	1.11	10.75	41.89	60.23
	Moderate (15-30%)	51.32	4.41	0.9	8.59	43.89	60.35
	Gentle (0-15%)	52.66	4.04	0.82	7.66	44.62	62
pH	Steep (>30%)	5.07	0.47	0.1	9.35	4.43	6.07
	Moderate (15-30%)	5.33	0.53	0.11	9.89	4.59	6.4
	Gentle (0-15%)	5.64	0.46	0.09	8.19	4.94	6.38
Organic Carbon (%)	Steep (>30%)	1.72	0.48	0.1	27.78	1.05	2.45
	Moderate (15-30%)	2.06	0.57	0.12	27.67	1.25	3.08
	Gentle (0-15%)	2.14	0.59	0.12	27.71	1.35	3.06
Organic Matter (%)	Steep (>30%)	2.96	0.82	0.17	27.79	1.81	4.22
	Moderate (15-30%)	3.55	0.98	0.2	27.67	2.16	5.31
	Gentle (0-15%)	3.69	1.02	0.21	27.73	2.33	5.28
Total Nitrogen (%)	Steep (>30%)	1.55	1.61	0.33	104.08	0.14	4.67
	Moderate (15-30%)	1.95	2.1	0.43	107.93	0.15	5.85
	Gentle (0-15%)	2.94	1.83	0.37	62.04	1.28	5.8
Phosphorus (kg/ha)	Steep (>30%)	10.33	10.83	4.81	0.98	4.88	20.33
	Moderate (15-30%)	12.5	12.50	5.66	1.15	5.48	24.00
	Gentle (0-15%)	16.38	16.38	6.35	1.30	6.90	25.44
Calcium (mg/kg)	Steep (>30%)	66.07	18.79	3.84	28.44	29.02	88.71
	Moderate (15-30%)	89.36	16.05	3.28	17.96	61.61	116.96
	Gentle (0-15%)	90.10	17.19	3.51	19.08	57.14	117.41
Magnesium (mg/kg)	Steep (>30%)	86.13	33.52	6.84	38.92	33.50	138.00
	Moderate (15-30%)	132.22	56.09	11.45	42.42	38.60	214.00
	Gentle (0-15%)	122.47	51.35	10.48	41.93	62.00	248.00
Sulfur (mg/kg)	Steep (>30%)	3.47	1.00	0.20	28.87	2.09	5.10
	Moderate (15-30%)	4.20	1.19	0.24	28.24	2.25	6.07
	Gentle (0-15%)	4.13	0.89	0.18	21.58	2.96	5.80
Potassium (kg/ha)	Steep (>30%)	167.03	48.33	9.86	28.93	97.23	240.55
	Moderate (15-30%)	150.53	29.66	6.05	19.70	122.75	223.16
	Gentle (0-15%)	166.74	52.67	10.75	31.59	95.50	274.55

Table 2: ANOVA for selected soil physico-chemical properties.

		Sum of Squares	df	Mean Square	F	Sig.
Bulk density (g/cm^3)	Between Groups	0.04	2.00	0.02	3.19	0.05
	Within Groups	0.48	69.00	0.01		
	Total	0.52	71.00			
Porosity (%)	Between Groups	48.68	2.00	24.34	1.12	0.33
	Within Groups	1504.85	69.00	21.81		
	Total	1553.52	71.00			
pH	Between Groups	3.92	2.00	1.96	8.20	0.00
	Within Groups	16.47	69.00	0.24		
	Total	20.38	71.00			
Organic Carbon (%)	Between Groups	2.43	2.00	1.21	4.03	0.02
	Within Groups	20.81	69.00	0.30		
	Total	23.24	71.00			
Organic Matter (%)	Between Groups	7.21	2.00	3.61	4.02	0.02
	Within Groups	61.92	69.00	0.90		
	Total	69.13	71.00			
Total Nitrogen (%)	Between Groups	24.67	2.00	12.34	3.58	0.03
	Within Groups	237.99	69.00	3.45		
	Total	262.67	71.00			
Phosphorus (kg/ha)	Between Groups	388.70	2.00	194.35	6.10	0.00
	Within Groups	2196.87	69.00	31.84		
	Total	2585.57	71.00			
Calcium (mg/kg)	Between Groups	8963.53	2.00	4481.76	14.84	0.00
	Within Groups	20844.13	69.00	302.09		
	Total	29807.66	71.00			
Magnesium (mg/kg)	Between Groups	28321.77	2.00	14160.88	6.15	0.00
	Within Groups	158848.90	69.00	2302.16		
	Total	187170.67	71.00			
Sulfur (mg/kg)	Between Groups	7.83	2.00	3.91	3.66	0.03
	Within Groups	73.78	69.00	1.07		
	Total	81.61	71.00			
Potassium (kg/ha)	Between Groups	4281.91	2.00	2140.96	1.07	0.35
	Within Groups	137769.63	69.00	1996.66		
	Total	142051.54	71.00			

Table No. 3: Pearson's correlation matrix for selected soil physico-chemical properties

	Porosity	pH	OM	TN	P	Ca	Mg	S	K
Porosity	1								
pH	0.23*	1							
OM	-0.05	-.42**	1						
TN	-0.17	-0.15	0.71**	1					
P	0.38**	0.51**	-0.36**	-0.57**	1				
Ca	0.26*	0.37**	0.11	-0.2	0.54**	1			
Mg	0.26*	0.2	-0.10	-0.54**	0.58**	0.62**	1		
S	0.03	-0.14	0.58**	0.49**	-0.1	0.32**	0.11	1	
K	0.25*	0.36**	-0.39**	-0.48**	0.53**	0.41**	0.46**	-0.16	1

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed).

Nutrient Index of Soils in the Study Area

The nutrient index (NI) values of selected soil nutrients viz. N, P and K were calculated using on the following equation[23].

$$\text{Nutrient Index (NI)} = (NL*1 + NM*2 + NH*3)/ NT$$

Where, NL, NM and NH are number of samples falling in low, medium and high classes of nutrient status respectively and NT is the total number of samples analyzed for a given area.These nutrient index values were then characterized as Nutrient Index category I, II and III. Based on Table No. 4, the fertility index along with the corresponding nutrient index categories for the soil under study area are given in Table No. 5. According to the information given in Table No. 5, status of N was found to be high. In line with this finding, Motsar[24] reported high nitrogen fertility status in Mizoram (NI= 2.72). A higher quantity of N corresponds to higher amounts of OM[21]. In the other hand P and K attained a medium status. Increased soil fertility under mature scattered trees has also been reported by other researchers[3-25].

Table No. 4: Nutrient Index with Range and Remarks

Nutrient Index	Range of soil nutrients	Fertility Level
I	Below 1.67	Low
II	1.67-2.33	Medium
III	Above 2.33	High

Table No. 5: Soil fertility status of the study area with respect to soil nutrient index

Nutrients	NI values	NI	Fertility Status
N (%)	2.8	III	High
P (kg/ha)	1.67	II	Medium
K (kg/ha)	1.94	II	Medium

CONCLUSION

All the soil properties were significantly affected by slope gradient except for soil porosity and available potassium. The result of the present study indicated that soil reaction varied from strongly acidic to moderately acidic. According to the soil fertility tests based on the calculated nutrient index of N, P and K, the soils of Arecanut Plantation showed high to low fertility status. However, the declined in soil physico-chemical properties were observed from steep slope to gentle slope which could be due to past soil erosion and runoff effect that removed soil organic matter and other plant nutrients. The unexpectedly high contents of organic matter and total nitrogen may be due to management factors like application of Farm Yard Manure (FYM) and green manures at regular intervals by the growers[26]. Furthermore, in relation to the addition of nutrients in the soil and minimizing the effects of erosion the residues from the clearing of grasses/under growths should be used to cover the soil surface[27], proper management practices such as proper land leveling, balanced intercropping, applications of FYM and green manuring at regular interval, terracing should be considered. Therefore, the overall data indicated that arecanut plantation has the capability to recover soil to its original condition in both physical and chemical properties for improved production on sustainable basis.

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