SLOPE LENGTHS EFFECT ON SOIL LOSS BY USING UNIVERSAL SOIL LOSS EQUATION IN SOME AGRICULTURAL SOILS OF MANIPUR

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ABSTRACT

Soil erosion being a complex process that depends on soil properties, ground slopes, vegetation and rainfall amount and intensity, a field experiment under natural rainfall and slope length for the inter rill soil erosion in two types of soils viz. Alfisols (hill soils) and Entisols (Valley soils) at Imphal, Manipur (24°33′ to 25°55' N latitude and 93°42' to 94°7' E longitude and 790 m above mean sea level) was estimated by using Universal Soil loss equation. Soil loss due to natural runoff on different slopes ranges from 36.78 to 48.89 ton ha^{-1} yr^{-1} (Alfisols) and 50.15 to 63.16 ton ha^{-1} yr^{-1} (Entisols)in 2008 and 42.59 ton ha^{-1} yr^{-1} to 53.63 ton ha^{-1} yr^{-1} in Alfisol and 58.18 ton ha^{-1} yr^{-1} to 73.28 ton ha^{-1} yr^{-1} in Entisol sin 2009. Rainfall intensity and the slope length exponent greatly influenced runoff. The predictive soil loss equation is statistically significant and observed fitness more than 98 percent.

Key words: *Inter rill erosion, Rainfall intensity, Slope length, Universal Soil loss Equation (USLE), Alfisols, Entisols.*

INTRODUCTION

Soil erosion, a complex process that depends on soil properties, ground slopes, vegetation and rainfall amount and intensity has almost universally well known as a serious threat to men's well-being. Changes in land use are widely recognized as capable of greatly acceleration to soil erosion [1,2,3] and it has long been recognized that erosion in excess of soil production would eventually result in decreased agricultural potential [4,5,6] .In India around 1,750,000 sq.km out of the total geographical area 3,280,000 sq. km is prone to soil erosion i.e. about 53% of the total land area is prone to soil erosion [7] and around 16.4 t ha-1(5334 m-tonnes) of soils are detached annually [8,9,10].

Slope length is one of the most variable components of empirical model in the Universal Soil Loss Equation (USLE) [11]. According to Zingg [12] the soil loss was three-fold by increasing two-fold slope length while Laflen and Saveson [13] observed that the soil loss was linearly increased with increasing the slope length. Soil loss was increased around 1.5 times upon doubling the slope length [14, 15]. However, there was also reported with the insignificant result of soil loss with increasing slope length [16, 17].The aim of the present study was to determine the spatial distribution of soil loss by pre-monsoon rain with effect of different slope lengths and soil types of agricultural soils in Manipur by using USLE.

MATERIALS AND METHODS

Study area

The present study was conducted at experimental field of HRDRI (Human Resource Development and Research Institute), Canchipur, Imphal, Manipur. It lies between 24°33' to 25°55' N latitude and 93°42' to 97°7' E longitude and 790 m above the mean sea level.

Slope length and soil types

Micro plots were of three lengths *i.e.* 20^{ft}, 40^{ft} and 60^{ft} and each plot of 2^{ft}wide with 2% slope gradient. Two common agricultural soils in Manipur *viz.* hill soil (red soil) and valley soils (dark soil), were filled in these micro plots. The slope length factor is the ratio of soil loss from the field slope length to that from the 22.13m (72.6^{ft}) length plots under identical conditions. Ratio of rill and inter-rill erosion B was calculated as

B = (Sin θ /0.0896)/ [3 sin) 0.8 + 0.56] [18]

Where, B is the rill- inter-rill erosion ratio and θ =Slope angle

m = B/(1+B) [18]

Where, m is the empirical slope exponent and B is the rill- inter-rill erosion ratio.

L = [x/72.6]^{m} [15]

Where L is the slope length, X is the horizontal projection of the slope length (ft) and M is empirical slope length

Run off and Soil loss

Runoff amount was measured after every rainstorm event by using the rational method. This method is expressed by an equation

Q=CIA/360 [19]

Where, Q is the rate of runoff in cubic meters per sec, I is the intensity in mm/hr, A is the catchment area in hectares and C is a dimensionless runoff coefficient.

Soil loss was calculated using USLE for the two consecutive years of pre-monsoon rain i.e. 2008 and 2009. The equations of soil loss used in this present investigation are as follows:

A=RKLSCP

Where, A is the amount of soil erosion (ton/ha/yr), R is the rainfall runoff erosivity factor, K is the soil erodibility factor, L is the slope length, S is the gradient of erosion slope, C is the cover management factor and P is the support practice factor.

RESULT AND DISCUSSION

Slope length and runoff

The intensity of rain and their distribution impact to soil surface and causes runoff was observed. Slope length affect the runoff as the slope length increases, the rate of runoff increases both in two different soil types *viz.* entisols and alfisols shows the runoff in red and dark soils with effect of different slope lengths at 2% slope gradient during pre-monsoon rain in 2008 and 2009 respectively was presented in Table 1 and Table 2.

Dimensionless coefficient (C) in red soil was 0.20 whereas in dark soil, it was 0.30. The catchment area (A) in ha for 20^{ft}, 40^{ft} and 60^{ft} were 3.72×10^{-4}, 7.43×10^{-4} and 1.12×10^{-3} respectively. The rate of runoff increasing with slope length and it also increase in dark soil as compare with red soil. In 2008, the rate of runoff in red soil ranges from 2.73×10^{-6} to $1.21 \times 10^{-5} m^3 sec^{-1}$ at 20^{ft}, 5.45×10^{-6} to $2.41 \times 10^{-5} m^3 sec^{-1}$ at 40^{ft}, 8.18×10^{-6} to $3.62 \times 10^{-5} m^3 sec^{-1}$ at 60^{ft}, whereas in dark soil the run off ranges from 4.09×10^{-6} to $1.81 \times 10^{-5} m^3 sec^{-1}$ at 20^{ft}, 8.72×10^{-6} to $3.62 \times 10^{-5} m^3 sec^{-1}$ at 40^{ft} and 1.23×10^{-5} to $5.43 \times 10^{-5} m^3 sec^{-1}$ at 60^{ft} . In 2009 the rate runoff in red soil at 20^{ft}, 40^{ft} and 60^{ft} ranges from 3.7×10^{-6} to $1.25 \times 10^{-5} m^3 sec^{-1}$, 7.4×10^{-6} to $2.55 \times 10^{-5} m^3 sec^{-1}$ and 1.12×10^{-5} to $3.82 \times 10^{-5} m^3 sec^{-1}$ respectively while in dark soil the rate of runoff ranges from 5.6×10^{-6} to $1.90 \times 10^{-5} m^3 sec^{-1}$ at 20^{ft} , 1.16×10^{-5} to $3.81 \times 10^{-5} m^3 sec^{-1}$ at 40^{ft} and 1.67×10^{-5} to $5.72 \times 10^{-5} m^3 sec^{-1}$ at 60^{ft} . The runoff in both the experimental years was significant at 0.05 levels. The finding evident that the slope lengths have clear impact to the soil erosion. Further the findings also highlight the impact of slope length on runoff depends upon soil types. The finding was in corroboration with the results reported by different workers [19].

Table 1: Impact of slope length on runoff Q (m^3/sec)during the pre-monsoon rain in 2008

Date	I_{30}(mmh^{-1})	Runoff Q (m^3sec^{-1}) Red soil			Runoff Q (m^3sec^{-1}) Dark soil		
		$^{**}20^{ft}$	**$^{**}40^{ft}$**	**$^{**}60^{ft}$**	**$^{**}20^{ft}$**	**$^{**}40^{ft}$**	**$^{**}60^{ft}$**
27/01/08	32.73	6.76×10^{-6}	1.35×10^{-5}	2.03×10^{-5}	1.10×10^{-5}	2.03×10^{-5}	3.04×10^{-5}
31/01/08	33.00	6.81×10^{-6}	1.36×10^{-5}	2.04×10^{-5}	1.02×10^{-5}	2.04×10^{-5}	3.07×10^{-5}
08/02/08	40.00	8.26×10^{-6}	1.65×10^{-5}	2.48×10^{-5}	1.23×10^{-5}	2.48×10^{-5}	3.72×10^{-5}
09/02/8(a)	46.90	9.68×10^{-6}	1.94×10^{-5}	2.91×10^{-5}	1.45×10^{-5}	2.91×10^{-5}	4.36×10^{-5}
09/02/8(b)	25.20	5.20×10^{-6}	1.04×10^{-5}	1.56×10^{-5}	7.80×10^{-6}	1.56×10^{-5}	2.34×10^{-5}
21/03/08	58.40	1.21×10^{-5}	2.41×10^{-5}	3.62×10^{-5}	1.81×10^{-5}	3.62×10^{-5}	5.43×10^{-5}
22/03/8(a)	29.40	6.07×10^{-6}	1.21×10^{-5}	1.82×10^{-5}	9.10×10^{-6}	1.82×10^{-5}	2.73×10^{-5}
22/03/8(b)	33.60	6.94×10^{-6}	1.39×10^{-5}	2.08×10^{-5}	1.04×10^{-5}	2.08×10^{-5}	3.12×10^{-5}
23/03/08	36.00	7.43×10^{-6}	1.49×10^{-5}	2.29×10^{-5}	1.12×10^{-5}	2.23×10^{-5}	3.34×10^{-5}
27/03/08	13.20	2.73×10^{-6}	5.45×10^{-6}	8.18×10^{-6}	4.09×10^{-6}	8.72×10^{-6}	1.23×10^{-5}
28/03/08	27.60	5.70×10^{-6}	1.14×10^{-5}	1.71×10^{-5}	8.55×10^{-6}	1.71×10^{-5}	2.56×10^{-5}
30/03/08	26.70	5.51×10^{-6}	1.10×10^{-5}	1.65×10^{-5}	1.10×10^{-5}	2.03×10^{-5}	3.04×10^{-5}
31/03/08	18.00	3.72×10^{-6}	7.43×10^{-6}	1.12×10^{-5}	1.02×10^{-5}	2.04×10^{-5}	3.07×10^{-5}
15/04/08	32.80	6.77×10^{-6}	1.35×10^{-5}	2.03×10^{-5}	1.23×10^{-5}	2.48×10^{-5}	3.72×10^{-5}

** Significant at 0.05 level.

Table 2: Impact of slope length on runoff Q (m^3/sec) during the pre-monsoon rain in 2009

Date	I_{30}(mm h^{-1})	Runoff Q (m^3sec^{-1}) Red soil			Runoff Q (m^3sec^{-1}) Dark soil		
		20ft	40ft	60ft	20ft	40ft	60ft
28/02/09(a)	39.69	8.2 x10^{-6}	1.63 x10^{-5}	2.45 x10^{-5}	1.30 x10^{-5}	2.46 x10^{-5}	3.67 x10^{-5}
28/02/09(b)	44.00	9.1 x10^{-6}	1.84 x10^{-5}	2.71 x10^{-5}	1.36 x10^{-5}	2.72 x10^{-5}	4.06 x10^{-5}
27/03/09	26.77	5.5 x10^{-6}	1.14 x10^{-5}	1.66 x10^{-5}	8.3 x10^{-6}	1.66 x10^{-5}	2.49 x10^{-5}
28/03/09	61.60	1.25 x10^{-5}	2.55 x10^{-5}	3.82 x10^{-5}	1.90 x10^{-5}	3.81 x10^{-5}	5.72 x10^{-5}
09/04/09	18.00	3.7 x10^{-6}	7.4 x10^{-6}	1.12 x10^{-5}	5.6 x10^{-6}	1.16 x10^{-5}	1.67 x10^{-5}
17/04/09(a)	42.60	8.8 x10^{-6}	1.76 x10^{-5}	2.63 x10^{-5}	1.31 x10^{-5}	2.63 x10^{-5}	3.94 x10^{-5}
17/04/09(b)	34.67	7.1 x10^{-6}	1.43 x10^{-5}	2.14 x10^{-5}	1.08 x10^{-5}	2.15 x10^{-5}	3.22 x10^{-5}
02/05/09	22.33	4.6 x10^{-6}	9.22 x10^{-6}	1.37 x10^{-5}	6.9 x10^{-6}	1.39 x10^{-5}	2.07 x10^{-5}
11/05/09	25.38	5.2 x10^{-6}	1.05 x10^{-5}	1.56 x10^{-5}	7.9 x10^{-6}	1.57 x10^{-5}	2.36 x10^{-5}
14/05/09	57.00	1.17 x10^{-5}	2.31 x10^{-5}	3.54 x10^{-5}	1.76 x10^{-5}	3.53 x10^{-5}	5.29 x10^{-5}
18/05/09	35.40	7.3 x10^{-6}	1.46 x10^{-5}	2.19 x10^{-5}	1.09 x10^{-5}	2.19 x10^{-5}	3.28 x10^{-5}
24/05/09	38.14	7.9 x10^{-6}	1.58 x10^{-5}	2.36 x10^{-5}	1.19 x10^{-5}	2.37 x10^{-5}	3.54 x10^{-5}
25/05/09(a)	41.54	8.6 x10^{-6}	1.72 x10^{-5}	2.58 x10^{-5}	1.28 x10^{-5}	2.56 x10^{-5}	3.85 x10^{-5}
25/05/09(b)	36.60	7.6 x10^{-6}	1.50 x10^{-5}	2.27 x10^{-5}	1.13 x10^{-5}	2.27 x10^{-5}	3.46 x10^{-5}
26/05/09	30.00	6.1 x10^{-6}	1.24 x10^{-5}	1.85 x10^{-5}	9.3 x10^{-6}	1.85 x10^{-5}	2.79 x10^{-5}

** Significant at 0.05 level.

Soil erosion by USLE

The LS factor in soil erosion by USLE is the erosion ratio of rill and inter rill. Table 2 shows the LS effect on soil loss with respect to different slope lengths.

Table 2: Impact of slope length on LS factor

Sl No	Slope length	B	M	L	S	LS
1.	20	0.262	0.21	0.7628	0.1437	0.10962
2.	40	0.262	0.21	0.88234	0.1437	0.12679
3.	60	0.262	0.21	0.96076	0.1437	0.13806

The present finding indicates that the values of slope exponent 0.21, the finding was in agreement with that of other workers from different parts of the world. The USLE plot data [18] showed that the slope length exponent may derive from 0 to 0.9.

Soil loss by the Universal soil loss equation (USLE) with effect of different slope length and different soil types was shown in Table 3 and Table 4 for the year 2008 and 2009 respectively. In 2008, soil loss in red soil at 20^{ft} slope length was in the range of 12.84 t ha^{-1}yr^{-1} to 71.56 t ha^{-1}yr^{-1}, at 40^{ft} slope length soil loss ranges from 14.85 t ha^{-1}yr^{-1}to 82.77 t ha^{-1}yr^{-1}and at 60^{ft} slope length the soil loss ranges from 16.17t ha^{-1}yr^{-1} to 90.12t ha^{-1}yr^{-1} whereas in dark soil the soil loss ranges from 17.50t ha^{-1}yr^{-1} to 97.59t ha^{-1}yr^{-1} at 20^{ft} slope length, 20.25t ha^{-1}yr^{-1} to 112.87t ha^{-1}yr^{-1} at 40^{ft} slope length and 22.05t ha^{-1}yr^{-1} to 122.90t ha^{-1}yr^{-1} at 60^{ft} slope length. In 2009, the soil loss (A) during pre-monsoon rain at 20^{ft} ranges of 18.45 to 76.10t ha^{-1}yr^{-1}, at 40^{ft} the soil loss ranges from 21.35 to 87.97t ha^{-1}yr^{-1} , and at 60^{ft} the loss ranges from 23.25 to 95.75t ha^{-1}yr^{-1} while in dark soil the ranges of soil loss at 20^{ft}, 40^{ft} and 60^{ft} was 25.22 to 103.7t ha^{-1}yr^{-1}, 29.15 to 119.9t ha^{-1}yr^{-1} and 31.69 to 130.7t ha^{-1}yr^{-1} respectively.

Analysis on the present finding of soil loss by the formula USLE in 2008, it is clear that the plot length of 20^{ft}, 40^{ft} and 60^{ft} in red soil, the soil loss scored with 36.78t ha^{-1}yr^{-1},42.54t ha^{-1}yr^{-1}and 48.89t ha^{-1}yr^{-1} respectively as the mean value of the of the observations. In dark soil type the soil loss with different plot lengths of 20^{ft}, 40^{ft} and 60 ^{ft} scored with mean value of 50.125t ha^{-1}yr^{-1},57.865t ha^{-1}yr^{-1}and 63.162t ha^{-1}yr^{-1} respectively at 2% slope. In 2009, the mean soil loss in red soil accord with 42.59t ha^{-1}yr^{-1} at 20^{ft}, 49.36t ha^{-1}yr^{-1} at 40^{ft} and 53.68t ha^{-1}yr^{-1} at 60^{ft} while in dark soil the average soil loss at 20^{ft}, 40^{ft} and 60^{ft} accord with 58.18t ha^{-1}yr^{-1}, 67.31t ha^{-1}yr^{-1} and 73.28t ha^{-1}yr^{-1} respectively. It is evident that length of plot distinctly affects the soil loss caused by rain in both the years. Erosion rates in the red soil of Chottanagpur plateau accord a soil loss value of 10 to 15 mg/ha/yr (4.5 to 7 tons/acre/yr) [9].

At Vasad study on soil loss (t ha^{-1}) at 11, 22 and 44 m lengths plots on 2% slope accounts 41.2, 45.7, 47.4 showing the soil loss has increased with the slope length up to 44m [20]. Studies on plots of 25, 37.5, 50 and 60 m length 2 % slope at Kharagpur showed that the soil loss increased with increased in length of plot up to 50 m[21]. Similarly the finding of higher in soil loss in higher slope length was in corroborative with the findings of other workers in different places [15].

Table 3: Impact of different slope length in soil loss(A) by USLE at 2% slope during pre-monsoon rain 2008 at Canchipur, Imphal Manipur

Date	Soil loss A (t ha^{-1} yr^{-1}) in red soil			Soil loss A (t ha^{-1} yr^{-1}) in dark soil		
	**20ft	**40ft	**60ft	**20ft	**40ft	**60ft
27/01/08	36.81	42.57	46.36	50.19	58.05	63.21
31/01/08	37.57	43.54	64.52	51.23	59.25	64.52
08/02/08	46.43	53.71	58.48	63.32	73.23	79.74
09/02/08(a)	55.72	64.45	70.17	75.89	87.88	95.69
09/02/08(b)	27.28	31.56	34.36	37.20	43.03	46.85
21/03/08	71.56	82.77	90.12	97.59	112.87	122.90
22/03/08(a)	32.60	37.71	41.06	44.46	51.42	55.99
22/03/08(b)	38.03	43.98	47.89	51.85	57.98	65.31
23/03/08	41.15	47.60	70.67	56.11	64.90	70.61
27/03/08	12.84	14.85	16.17	17.51	20.25	22.05
28/03/08	30.31	35.06	38.17	41.33	47.81	52.06
30/03/08	29.17	33.74	36.74	39.78	46.01	50.09
31/03/08	18.44	21.33	23.22	25.14	29.09	31.67
15/04/08	36.99	42.78	46.58	50.44	58.34	63.52

** Significant at 0.05 level.

Table 4: Impact of different slope length in soil loss(A) by USLE at 2% slope pre-monsoon rain 2009 at Canchipur, Imphal, Manipur

Date	Soil loss A (t ha^{-1} yr^{-1}) Red soil			Soil loss A (t ha^{-1} yr^{-1}) Dark soil		
	20ft	40ft	60ft	20ft	40ft	60ft
28/02/09(a)	46.03	53.25	57.97	62.72	72.64	79.10
28/02/09(b)	51.72	59.94	65.26	70.65	81.75	88.89
27/03/09	29.27	33.83	36.83	39.87	46.18	50.31
28/03/09	76.10	87.97	95.79	103.7	119.9	130.7
09/04/09	18.45	21.35	23.25	25.22	29.15	31.69
17/04/09 (a)	48.93	57.79	62.86	68.08	78.68	85.76
17/04/09 (b)	39.40	45.59	49.61	53.72	62.18	67.70
02/05/09	23.72	27.43	29.85	32.42	37.45	40.73
11/05/09	27.52	31.82	34.67	37.51	43.41	47.24
14/05/09	69.62	80.52	87.69	94.93	109.7	119.6
18/05/09	40.35	46.68	50.08	55.09	63.74	69.35
24/05/09	43.99	50.88	55.42	59.98	69.39	75.47
25/05/09(a)	48.46	56.14	61.07	66.15	76.53	83.29
25/05/09(b)	41.94	48.54	52.82	57.27	66.26	72.03
26/05/09	33.42	38.60	42.05	45.46	52.63	57.32

** Significant at 0.05 level.

Erosion in the sandy loam (red soil) of Chhotanagpur plateau accord a soil loss value of 10 to 15 mg ha^{-1} yr^{-1} (4.5 to 7 t ha^{-1} yr^{-1}) [9]. The soil loss (A) compute by USLE in an experiment record 23 t ha^{-1} 56.89t $ha^{-1}yr^{-1}$ as reported by **Anthoni [22]**. Further soil loss (A) by USLE in slope estimated with a range from 58.54-340 t $ha^{-1}yr^{-1}$ at 30^{ft} slope length and 70.84 to 471.47 t $ha^{-1}yr^{-1}$ at 60^{ft} slope length with relation to rainfall intensity of 30-45 mm hr^{-1} and more than 45 mmh^{-1} [11]. The research on the impact of soil erosion on agricultural lands in Korea on upland above 10% attained 32.0t ha^{-1} [23].

The present finding vividly showed the slope length impacts on soil erosion and corresponding to soil loss. The relationship between these two parameters strike high resulting the linearity by the regression equation between soil loss and slope length in two different types of soil during two consecutive years of pre-monsoon rains of 2008 and 2009 viz. y=0.30269x + 30.623, R^2=0.9992 for Alfisol of 2008; y=0.3251x + 44.053, R^2=0.9886 for Entisol of 2008; y=0.2772x + 37.457, R^2=0.98 for Alfisol of 2009 and y=0.3773x + 44.51.162, R^2=0.98 for Entisol of 2009 and graphically shown in Fig 1 and 2 respectively. Thus the finding evidence the linearity of relationship between slope length and soil loss with fitness upto the R^2 value ranging from 0.98 to 0.99.

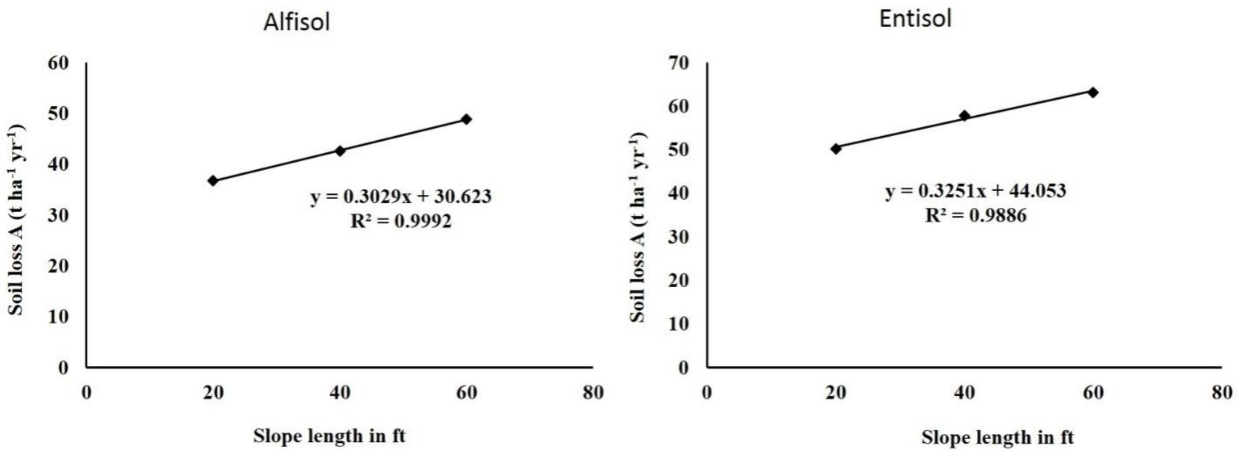

Fig 1: Regression line of soil loss due to different slope length in (a) red soil (Alfisol) (b) dark soil (Entisol) during pre-monsoon rain of 2008

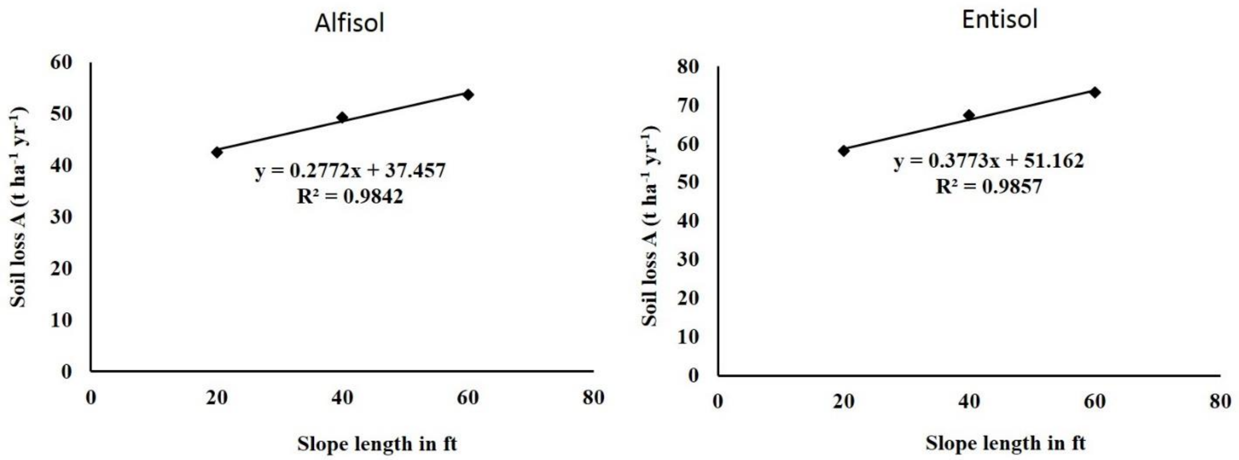

Fig 2: Regression line of soil loss due to different slope length in (a) red soil (Alfisol) (b) dark soil (Entisol) during pre-monsoon rain of 2009

The finding further confirmed soil loss by erosion increases correspondingly with increasing intensity of rain and slope length. The slope length exponent showed extensive sensitivity to duration and intensity of rainfall and concurred to runoff. The finding also highlighted the importance of soil erosion by natural rain water on different slope length on soils of Alfisols (hill soil and Entisols (valley soil) of Manipur, North East India and add tiny information to the vast knowledge of soil Science and provide new room for further investigation to different field of applied sciences for increasing sustainable productivity.

CONCLUSION

The present investigation signifies the soil loss increases linearly with increasing slope length. The linearity highlight the essentiality of precautionary measures in adoption of productivity practices of plantation, horticulture, agriculture and land uses programmes so as to maintain sustainable development by proper utilization of land without deteriorating soil by dreadful erosion.

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