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Soil loss prediction model under different land uses in scarcity zone of western Maharashtra

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ABSTRACT : Soil loss prediction model considering crop canopy as one of the most important parameters was developed by conducting a runoff plot based study for effective crop planning and reducing the erosion losses from agricultural lands. The study was carried out during 2007 to 2010 on a set of eight standard runoff plots on 1% slope at AICRPDA, Solapur. The treatments comprised of seven common crops and intercrops of the region (T_1- Greengram, T_2- Pearl millet, T_3- Pearl millet + Cowpea (6:3), T_4- Pearl millet + Pigeonpea (2:1), T_5- Sunflower + Pigeonpea (2:1), T_6- Sunflower, T_7- Blackgram) and one runoff plot was maintained as cultivated fallow (T_8). The field crops were sown during middle of the July on contours and standard agronomic practices were followed. The observations on strom-wise runoff, soil loss and canopy were recorded to develop a soil loss prediction model. On the basis of storm-wise data on crop canopy, runoff, soil loss, rainfall and rainfall intensity for 30 minutes (I_{30}), a multiple linear regression model was developed for prediction of soil loss under different treatments. Analysis of variance of regressions revealed that in most of the cases the effect of regression was significant and in some of the cases the values of co-efficient of determination reached to a level of 0.98 which indicated that the relative contribution of different independent variables (crop canopy, runoff, rainfall and rainfall intensity) on dependent variable (soil loss) was upto 98%. The model developed can be used for estimating the soil loss from medium deep soils up to 1 % slope under different land uses in scarcity zone of western Maharashtra under similar set of conditions with fair degree of accuracy for effective soil and water conservation planning for minimizing erosion.

KEY WORDS : Crop canopy, Soil loss prediction model, Rainfall, Runoff, Soil loss, Land use

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Erosion prediction is very necessary for assessing the quantum of erosion losses under different land uses and managing the soil and water resources in a better manner. Many workers have tried to evaluate mathematical relations to predict runoff and soil loss (Awasthi *et al.*, 1990; Bharadwaj and Sindhwal, 1998; Kale *et al.*, 1998). The soils of western Maharashtra scarcity zone are black vertisol which are highly erodible because these soil swells after raining resulting in low infiltration. The undulating topography and high intensity rains also contribute to severe erosion . At same rainfall and soil characteristics, the quantum of erosion losses varies under different land uses depending upon canopy coverage available on the ground surface. Bhardwaj and Sindhwal (1998) also reported a soil loss prediction model considering rainfall, runoff and canopy as independent parameters. Similarly, Channappa (1994) and Kumar and Satyanarayana (1994) also developed runoff and soil loss prediction models for a watershed considering hydrologic, geomorphic, climatic and vegetative parameters. Dev Narayan and Bhushan (2003) also developed soil loss prediction model considering rainfall, runoff, crop canopy, I_{30} and EI_{30} for deep alluvial soils of ravine region. There is meagre information available on the aspect of erosion prediction for the scarcity zone of western Maharashtra. In view of this, present runoff plot based study was undertaken to develop a soil loss prediction model considering the different parameters and including crop canopy as one of the important parameters for effective soil and water conservation planning for minimizing the erosion.

■ METHODOLOGY

The experiment was conducted on a set of eight standard runoff plots during *Kharif* season of 2007 to 2010 at Dry Farming Research Station, All India Co-ordinate Research Project for Dryland Agriculture, Solapur which is located in the scarcity zone of western Maharashtra (Latitude - 17^{0}41'N,

Table A : Physical properties of soils of experimental plots

Coarse fragment	:	2.30%	Depth	:	60 cm
Coarse sand	:	5.2 %	FC	:	38.77%
Fine sand	:	15.66%	PWP	:	18.16%
Silt	:	20.17%	Available water content	:	20.61%
Clay	:	58.97%	Maximum water holding capacity	:	60.05%
Bulk density	:	1.19 g cm^{-3}	Coefficient of Permeability	:	8 mm/h

Table B : Chemical properties of soils of experimental plots

pH	:	7.88	Organic carbon, %	:	0.45
EC, dSm^{-1}	:	0.10	$CaCO_3$, %	:	3.62
Organic matter, %	:	0.77	Available N:P:K, kg/ha	:	143:33:633

Table C : Storm wise I_{30} and crop canopy for different treatments (2007-2010)

Storm date	Rainfall, mm	I_{30}, mm/h	Crop canopy, %						
			T_1	T_2	T_3	T_4	T_5	T_6	T_7
25/07/2007	49.6	36.0	35.0	36.0	32.0	33.0	47.0	23.0	39.0
29/07/2007	24.2	20.0	35.1	35.0	40.7	35.0	48.0	30.1	35.3
12/08/2007	13.0	14.0	28.0	27.0	43.0	35.2	48.4	33.0	24.0
26/08/2007	58.4	54.0	24.0	26.0	49.0	42.8	57.0	35.0	22.0
27/08/2007	13.2	22.0	17.3	21.3	50.1	44.0	63.1	36.2	9.3
30/08/2007	13.0	18.0	12.8	22.2	52.5	48.1	65.0	38.0	8.2
10/09/2007	14.0	3.0	--	34.5	66.7	60.0	71.5	42.5	8.0
13/09/2007	60.8	60.0	--	37.0	68.2	70.0	74.0	44.8	--
15/09/2007	16.2	28.0	--	38.1	69.0	72.2	75.8	45.0	--
19/09/2007	22.2	13.0	--	40.8	72.1	80.7	78.2	48.2	--
21/09/2007	21.5	8.0	--	42.5	73.3	81.2	80.2	54.7	--
29/09/2007	14.5	20.0		45.0	80.2	83.2	82.7	55.5	--
Mean			25.4	33.8	58.0	57.1	65.9	40.5	20.8
29/08/2008	32.4	3.4	13.0	11.2	23.2	20.0	18.0	20.0	14.0
03/09/2008	20.0	1.6	34.3	33.6	42.7	32.2	30.2	28.7	29.0
06/09/2008	32.0	2.0	35.0	35.6	45.0	34.0	32.5	32.2	30.0
08/09/2008	74.0	4.6	35.8	36.0	45.2	35.0	33.0	35.0	29.5
23/09/2008	24.2	1.0	38.5	38.1	50.0	40.8	40.3	40.2	28.0
04/10/2008	29.2	2.4	-	41.0	67.0	59.0	47.0	47.0	-
Mean			24.2	32.6	45.5	36.8	33.5	33.9	26.1
20/08/2009	41.0	8.0	38.0	34.0	39.0	33.0	43.0	31.0	30.0
24/08/2009	48.8	1.5	36.5	34.3	39.2	39.1	44.2	32.5	33.0
26/08/2009	32.5	8.0	36.5	37.0	40.0	41.1	45.3	33.8	34.5
29/09/2009	40.5	10.0	-	54.2	69.3	69.1	53.7	45.1	-
30/09/2009	36.0	7.0	-	59.0	67.0	77.0	57.0	46.0	-
01/10/2009	59.4	12.0	-	50.1	60.0	68.2	55.1	43.0	-
02/10/2009	39.5	16.0	-	-	-	43.3	52.7	-	-
03/10/2009	27.5	7.0	-	-	-	40.2	51.1	-	-
Mean			37.0	44.8	52.4	51.4	50.3	38.6	32.5
01/07/2010	71.0	6.0	8.0	5.0	9.0	9.0	12.0	11.5	13.0
21/07/2010	26.0	1.3	51.0	20.0	38.0	26.0	33.0	54.0	51.0
12/08/2010	34.2	2.6	61.0	44.0	60.0	53.0	46.0	62.0	63.0
29/08/2010	32.2	2.1	80.0	52.0	79.0	66.0	64.0	71.0	72.0
Mean			50.0	30.2	46.5	38.5	38.8	49.6	49.7

Table D : Crop canopy, runoff and soil loss as influenced by different treatments (2007-2010)

	Crop canopy, %				Mean	Runoff, mm				Mean	Soil loss, kg ha^{-1}				Mean
	2007	2008	2009	2010		2007	2008	2009	2010		2007	2008	2009	2010	
T_1	25.4	24.2	37.0	50.0	34.1	7.1	39.1	70.8	11.5	32.1*36.3	22	31	55	22	32.5*38.1
T_2	33.8	32.6	44.8	30.2	35.3	4	31.9	54.4	21.2	27.9*44.6	24	26	43	34	31.7*39.6
T_3	58.0	45.5	52.4	46.5	50.6	2.1	23.2	52.2	14.6	23.0*54.4	17	11	41	27	24.0*54.3
T_4	57.1	36.8	51.4	38.5	45.9	3.4	26	54.9	22.8	26.8*46.8	08	18	47	31	26.0*50.5
T_5	65.9	33.5	50.3	38.8	47.1	3.5	28.8	57.5	13.7	25.9*48.6	18	19	48	22	26.7*49.1
T_6	40.5	33.9	38.6	49.6	40.6	4.8	29.8	59	9.4	25.8*48.8	29	31	43	23	31.5*40.0
T_7	20.8	26.1	32.5	49.7	32.3	8.7	36.8	65.7	7.3	29.6*41.3	33	35	56	22	36.5*30.5
T_8	--	--	--	--	--	15.8	54.3	106	25.4	50.4	41	40	61	68	52.5

* indicates percent decrease over control T_8

Longitude - 75^{0}56'E and 483.6 m above MSL). Each runoff plot having an area of 0.15 ha with 1% slope was used for the study. The physical and chemical properties of the soils of experimental runoff plots are given in Table A and B, respectively. The structure of soil is sub angular blocky and textural class is clayey.

The western Maharashtra scarcity zone represents semi-arid ecosystem, AER No.6, Deccan plateau, hot semi-arid eco region with shallow and medium deep black soils. The pattern of rainfall is bimodal. The rains are received through South-West monsoon during June to September having average annual rainfall of 723 mm received in 40-45 rainy days. Usually on set of monsoon is during first week of June. Nearly 80 to 85 per cent of average annual rainfall is received during June to September.

The experiment was conducted considering common field crops and intercrops of the region as treatments with T_1- Greengram, T_2- Pearl millet, T_3- Pearl millet + Cowpea (6:3), T_4- Pearl millet + Pigeonpea (2:1), T_5- Sunflower + Pigeonpea (2:1), T_6- Sunflower, T_7- Blackgram and T_8 - Cultivated fallow. The cultivars Phule Vaibhav of greengram, Shraddha of pearl millet, Phule Pandhari of cowpea, Vipula of pigeon pea, Bhanu of sunflower and TAU-1 of blackgram were used. The crops were usually sown in the middle of the July on contours and recommended agronomic practices were followed. The cultivated fallow plot was maintained as suggested by Singh *et al.* (1981). During four years from 2007 to 2010, the rainfall data were collected after each storm. Using the raingauge chart of recording type raingauge the I_{30} *i.e.*, maximum 30 minute intensity of rainfall was computed. The vegetation canopy was measured with the help of a canopy measurement frame after every storm. The details of rainfall amount, I_{30}, percentage crop canopy for all the thirty storms observed during four years are shown in Table C. Storm wise runoff was measured and runoff samples were collected for estimation of soil loss. The yearly and four years storms data on crop canopy, runoff, soil loss and maximum 30 minute rainfall was subjected to multiple linear regression analysis for estimating the effect of different parameters in each treatment on soil loss. The details of crop canopy, runoff and soil loss during 2007-2010 are shown in Table D. During, first three years, the soil loss was considered as function of crop canopy, rainfall, I_{30} and runoff. The runoff is function of rainfall and I_{30}. These two factors *i.e.*, rainfall and I_{30} were considered separately. Hence, during fourth year the runoff factor is eliminated and the equations for forth year and combined equation for four years was formed using soil loss as a function of crop canopy, rainfall and I_{30}.

■ RESULTS AND DISCUSSION

The experimental findings obtained from the present study have been discussed in following heads:

Regression model for prediction of soil loss:

On the basis of storm-wise data on canopy, runoff, soil loss, rainfall, rainfall intensity for 30 minutes duration (I_{30}) a multiple regression model was developed for predicting the soil loss under different treatments on the basis of individual year's storm as well as four years storm which is given in Table 1.

Soil loss prediction equations for different crops:

The soil loss prediction equations for different treatments are given in Table 1, which were developed by considering canopy cover (%), rainfall (mm), runoff (mm) and I_{30} (mm/h).

T_1: Green gram:

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 40%.

T_2: Pearl millet:

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 65%.

Table 1 : Soil loss prediction equations for different crops

Year	Soil loss prediction equation	n	F	R^2	r
T_1=Green gram					
2007	$Y=-5.214+0.022Ca-.582Ro+0.251Rf+0.053I_{30}$	12	**	0.89	0.94
2008	$Y=-1.226+0.220Ca-0.961Ro-.419Rf+8.6603I_{30}$	6	*	0.96	0.98
2009	$Y=-3.283-0.062Ca+2.221Ro-0.239Rf+0.154I_{30}$	8	*	0.81	0.90
2010	$Y=11.506-0.125Ca+0.092Rf-1.1829.567I_{30}$	4		0.99	0.99
Four year	$Y=-0.146-0.010Ca+0.151Rf-0.034I_{30}$	30	**	0.40	0.63
T_2=Pearl millet					
2007	$Y=-1.673-0.107Ca-3.043Ro+0.273Rf+0.049I_{30}$	12	**	0.92	0.96
2008	$Y=6.892-0.063Ca-3.270Ro+0.166Rf+4.440I_{30}$	6	*	0.98	0.99
2009	$Y=-.431+0.017Ca+1.256Ro+0.005Rf+0.016I_{30}$	8	*	0.76	0.87
2010	$Y=11.530-0.021Ca-0.492Rf+5.922I_{30}$	4		0.99	0.98
Four years	$Y=1.558-0.081Ca+0.167Rf-0.025I_{30}$	30	**	0.65	0.81
T_3=Pearl millet+ Cow pea					
2007	$Y=-1.635-.014Ca+0.722Ro+0.119Rf+0.032I_{30}$	12	**	0.91	0.95
2008	$Y=-103.08-0.399Ca+37.301Ro-0.153Rf+35.563I_{30}$	6	*	0.96	0.98
2009	$Y=-3.089+0.113Ca+2.351Ro+0.191Rf-0.427I_{30}$	8	*	0.94	0.97
2010	$Y=4.875+0.013Ca-0.234Rf+3.604I_{30}$	4		0.97	0.98
Four years	$Y=1.967-0.057Ca+0.128Rf-0.0004I_{30}$	30	**	0.55	0.74
T_4=Pearl millet+ Pigeon pea					
2007	$Y=-0.410-0.016Ca-0.266Ro+0.077Rf+0.007I_{30}$	12	*	0.82	0.90
2008	$Y=0.832-0.115Ca+2.041Ro-0.054Rf-0.192I_{30}$	6	*	0.95	0.97
2009	$Y=-17.281+0.028Ca+2.873Ro-0.015Rf +0.305I_{30}$	8	*	0.64	0.80
2010	$Y=5.556-0.024Ca-0.033Rf+1.504I_{30}$	4		0.98	0.99
Four years	$Y=1.1091-0.023Ca+0.139Rf-0.0894I_{30}$	30	**	0.60	0.76
T_5=Sunflower+ Pigeon pea					
2007	$Y=3.094-0.033Ca+6.639Ro-0.006Rf-0.039I_{30}$	12	**	0.94	0.97
2008	$Y=12.049-0.281Ca-0.608Ro-0.018Rf+1.173I_{30}$	6	*	0.97	0.99
2009	$Y=2.013-0.117Ca+0.759Ro-0.021Rf+0.364I_{30}$	8	*	0.45	0.67
2010	$Y=10.650-0.057Ca-0.543Rf+6.431I_{30}$	4		0.99	0.99
Four year	$Y=3.804-0.080Ca+0.113Rf+0.021I_{30}$	30	**	0.60	0.78
T_6=Sunflower					
2007	$Y=1.597-0.004Ca+8.519Ro-0.056Rf-0.030I_{30}$	12	**	0.993	0.99
2008	$Y=18.423-0.395Ca-1.172Ro+0.123Rf0.702I_{30}$	6	*	0.97	0.99
2009	$Y=-11.058+0.108Ca+2.010Ro+0.005Rf-0.186I_{30}$	8	*	0.97	0.98
2010	$Y=7.278-0.067Ca-0.051Rf+1.0281I_{30}$	4		0.98	0.99
Four year	$Y=2.166-0.093Ca+0.014Rf+0.034I_{30}$	30	**	0.70	0.83
T_7=Black gram					
2007	$Y=0.808-0.017Ca+4.726Ro-0.037Rf-0.021I_{30}$	12	**	0.994	0.99
2008	$Y=-7.926+0.379Ca-0.034Ro-0.508Rf-9.574I_{30}$	6	*	0.94	0.97
2009	$Y=-2.291-0.088Ca+1.010Ro+0.031Rf+0.092I_{30}$	8	*	0.63	0.79
2010	$Y=9.359-0.067Ca-0.328Rf+4.304I_{30}$	4		0.97	0.99
Four year	$Y=-2.024-0.007Ca+0.197Rf+0.020I_{30}$	30	**	0.60	0.77

where, Y=Soil loss ($kgha^{-1}$), Ca=Canopy (%), Ro=Runoff (mm), Rf=Rainfall (mm), I_{30}=Rainfall intensity for 30 minutes duration ($mmhr^{-1}$), n= Number of storm, R^2= Coefficient of determination, r= Multiple correlation co-efficient, F= 'F' test of significance for analysis of variance.
* and ** indicate significance of values at P=0.05 and 0.01, respectively

T_3: Pearl millet + Cowpea (6:3):

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 55%.

T_4: Pearl millet + Pigeonpea (2:1):

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 60%.

T_5: Sunflower + Pigeonpea (2:1):

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 60%.

T_6: Sunflower:

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 70%.

T_7: Blackgram:

Four years pooled analysis of variance revealed that multiple regression was significant. The relative contribution of different independent variables (canopy, rainfall and rainfall intensity) on dependent variable (soil loss) was 60%.

Soil loss prediction under crop cover and cultivated fallow condition:

In order to study the generalized effect of different parameters under crop cover, the storm wise data of different crops pertaining to canopy, runoff and soil loss were pooled and multiple regression model was fitted to work out the soil loss. The analysis of variance revealed that the co-efficient of determination ranged between 0.76 to 0.99 during individual years. The four years pooled analysis of variance revealed that the effect of regression was significant and the relative contribution of independent variables on dependent variable was 67%.

Under cultivated fallow condition, the pooled analysis of variance over four years revealed that the effect of multiple regression in soil loss prediction was significant and the co-efficient of determination ranged between 0.46 to 0.96 during individual years. The four years pooled analysis of variance revealed that the effect of regression was significant and the relative contribution of independent variables on dependent variable was 59%. The soil loss prediction under crop cover conditions and cultivated fallow condition are given in Table 2.

Crop cover condition:

To find out the effect of different parameters under crop cover, the storm wise data of different crops pertaining to canopy, runoff and soil loss was pooled and following multiple regression model is fitted to work out the soil loss.

$$\mathbf{Y = 2.948 - 0.096\,Ca + 0.139\,Rf - 0.012\,I_{30}}$$
$$\mathbf{(R^2 = 0.67, r = 0.82, n = 30, F\text{-test} = {**})}$$

Conclusion:

It was seen that in most of the cases the effect of different independent parameters was significant in soil loss prediction, which was evident from significant value of 'F' test and higher value of multiple correlation co-efficient (r) and co-efficient of determination (R^2), which showed the higher reliability of the

Table 2 : Soil loss prediction equation under crop cover and cultivated fallow condition

Year	Soil loss prediction equation	n	F	R^2	r
Under crop cover					
2007	$Y=0.150 - 0.074Ca + 0.158Rf - 0.015I_{30}$	12	**	0.92	0.96
2008	$Y=18.142 - 0.475Ca + 0.218Rf – 2.471I_{30}$	6	*	0.76	0.87
2009	$Y=6.570 - 0.162Ca + 0.096Rf + 0.083I_{30}$	8	*	0.79	0.88
2010	$Y=8.446 - 0.048Ca - 0.231Rf + 3.170I_{30}$	4		0.99	0.99
Four year	$Y=2.948 - 0.096Ca + 0.139Rf - 0.012I_{30}$	30	**	0.67	0.82
Cultivated fallow					
2007	$Y= -5.711 + 0.257 Rf + 0.090 I_{30}$	12	**	0.95	0.97
2008	$Y= -0.897 + 0.296 Rf - 1.833 I_{30}$	6	*	0.50	0.71
2009	$Y= 1.428 + 0.102 Rf + 0.232 I_{30}$	8	*	0.46	0.51
2010	$Y= 25.891 – 1.568 Rf + 18.436 I_{30}$	4		0.96	0.98
Four year	$Y= -3.543 + 0.308 Rf - 0.023 I_{30}$	30	**	0.59	0.76

where, Y=Soil loss ($kgha^{-1}$), Ca=Canopy (%), Ro=Runoff (mm), Rf=Rainfall (mm), I_{30}=Rainfall intensity for 30 minutes duration ($mmhr^{-1}$),
n= Number of storm, R^2= Coefficient of determination, r= Multiple correlation co-efficient, F= 'F' test of significance for analysis of variance.
* and ** indicate significance of values at P=0.05 and 0.01, respectively

equation.

The present model, Y = 2.948 - 0.096 Ca + 0.139 Rf - 0.012 I_{30} can be used for estimating the soil loss from medium deep soils up to 1 % slope under different land uses in scarcity zone of western Maharashtra [where, Y = Soil loss during each rainstorm (kg/ha), Ca = Crop canopy cover (%), Rf = Storm rainfall (mm) and I_{30} = Maximum 30 minute rainfall intensity of the storm (mm/h)] under similar set of conditions with fair degree of accuracy for effective soil and water conservation planning for minimizing erosion.

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