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MEASUREMENT OF SPLASH EROSION IN DIFFERENT COVER CROPS

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ABSTRACT

Splash erosion in land is affected by factors such as slope, meteorological factors, soil properties and plant cover. The objective of this research is to determine the effects of different cover crops and different slopes on splash erosion. The experiment was carried out in an open field on four different cover crops (control, vetch, barley, ryegrass) in two different slopes (4% and 9%) with a three replications in four months. Splash erosion is determined with the help of splash cups placed on the experiment plots. In the experiment, splash erosion decreased with the increase in cover percentage and the decrease in the slope. Splash erosion increases in control plots with the increase in rainfall. Correlation coefficient between kinetic energy of rainfall and splashing soil in control plots were determined as 0.83 in 4% slope and 0.84 in 9% slope.

Key words: Cover Crops, Soil Erosion, Splash Cups, Splash Erosion

INTRODUCTION

Soil erosion in Turkey is the most serious threat in the distortion of natural resources. In our country, factors such as topography, climate, not using land according to its capability, forest destruction, wildfires, early and overgrazing in pasture, fallowing in large agricultural fields and non-use of crop rotation increase losses resulting from soil erosion. Annual soil loss in Turkey according to the sediment measurements in rivers of Turkey is 500 million tons. However, this value only reflects suspended sediments found in the rivers of Turkey, and it does not cover losses resulting from splash on land surface and field displacement (Haktanır, 1997).

Water erosion is a process by which soil aggregates and primary particles are detached from the soil matrix, transported downslope by raindrops and flowing water, and deposited under certain energy-limiting conditions (Meyer et al. 1975). Four basic detachment and transport processes have been identified, including detachment by raindrops, detachment by flowing water, transport by raindrops, and transport by flowing water. Different types of erosion can occur within a field depending on soil detachment method, transport method, and detachment location (Nearing et al. 1994). The most common types of water erosion observed in agricultural fields are splash, sheet, rill and interrill erosion (Flanagan, 2002). When the falling raindrops hit the soil surface, they detach soil particles and cause them to splash into the air. This detachment process represents the formation of these soil splashes. Soil detachment rates by raindrop impact depend on several hydraulic flow characteristics, including raindrop impact size and mass, drop velocity, kinetic energy and water drop impact angle (Cruse et al., 2000). In addition, detachment rate is also strongly influenced by soil properties, including soil type, soil strength, bulk density, texture, cohesion, soil organic matter content, moisture content and infiltration capacity (Nearing et al., 1988). Raindrops falling on the surface of the soil break the soil masses into pieces and make them convenient for transportation with the help of runoff. The capacity of rainfall to transport soil by splash is a function of slope steepness, amount of rain, soil properties, micro topography and wind velocity (Meyer and Wischmeier, 1969).

Recent environmental and ecological awareness has started a resurgence in cover crop use. Although cover crops have been used for centuries, today's modern farmer has grown up in a generation which has replaced the use of cover crops with widespread use of fertilizers and herbicides. Cover crops have an important role in successful sustainable farming systems. Cover crops control soil erosion, improve soil quality and fertility, suppress weeds and provide insect control (Sarrantonio, M. 2007). Many researches have proposed an exponential decline in soil particle detachment with increasing canopy cover (Osborn, 1950; Elwell and Stocking, 1976), whereas others have shown that the interception of rainfall by a plant canopy can result in increases in rainfall intensity (Armstrong and Mitchell, 1987) and kinetic energy (Chapman, 1948; Brandt, 1989).

Rainfalls in Turkey generally occurs in fall, winter and spring. During this rainy period, massive wheat and barley cultivation occurs in every corner of the country. In regions where the climate is suitable after crops are grown. After crop cultivation is also common in the Çanakkale province. These two products are cultivated in Çanakkale region. During the winter period, crops such as vetch and peas are generally cultivated or fields are left fallow. A large part of the erosion is caused by pastures which undergo early grazing or overgrazing. 70 percent of pastures of the country are covered with grasses. Therefore, in the research one forage belonging to cool grass was selected.

The purpose of this study is to determine the effect of cover crops cultivated in two different slopes (4% and 9%) on splash erosion.

MATERIALS AND METHODS

Experiment was carried out in Technology and Agricultural Research Center of Çanakkale Onsekiz Mart University which is located near Sarıcaeli village, 3 km away from the Çanakkale city center. Data were complied from Directorate of Meteorology of Çanakkale province (Table 1). Some physical and chemical properties of soil used in the experiment are given in table 2. Particle size distribution was determined by the pipette method, using sodium hexamethaphosphate as a dispersing agent, with silt and clay fractions being determined after sieving to remove sand particles (Gee and Bauder, 1986). Total carbonate content was measured volumetrically (calcimeter) after treating with HCl (Nelson, 1982). Organic matter was formed by modified Walkley Black method (Nelson and Sommers, 1982). Soil pH and electrical conductivity (EC) were determined potentiometrically in a 1:2.5 ratio in H_2O (McLean, 1982; Rhoades, 1982). Available phosphorus (P) was determined by 0.5 M Na-bicarbonate extraction at a nearly constant pH of 8.5 (Olsen ve Sommers, 1982). Exchangeable K 1 N was determined with ammonium acetate and extraction method (Thomas 1982).

Table 1. During the experimentation time and long term temperature, relative humidity and total rainfall value in Çanakkale

	Average Temperature (ºC)		Average of Relative Humidity (%)		Total Rainfall (mm)	
	2006-2007	Long Term	2006-2007	Long Term	2006-2007	Long Term
Nov	10.3	11.4	86.4	82.0	33.9	91.7
Dec	7.4	8.1	85.0	83.0	25.6	103.3
Jan	9.3	6.3	76.2	83.0	30.2	88.5
Feb	5.6	6.3	75.1	81.0	48.4	63.1
Mar	9.7	8.3	75.5	80.0	151.5	63.8

Table 2. Some physical and chemical properties of experimental soil

Sand (%)	Silt (%)	Clay (%)	Texture Class	Organic Matter (%)
43.48	17.39	39.13	Clay Loam	1.53
Lime (%)	**pH (1:2.5)**	**Electrical Conductivity (1:2.5) (dS m^{-1})**	**P_2O_5 (kg da^{-1})**	**K_2O (kg da^{-1})**
7.65	7.51	0.60	6.38	249.47

Experiment was carried out in two different slopes (4% and 9%), four different cover crops (control, vetch, barley and ryegrass) in randomized parcels in factorial arrangements with three replications. Plot size is 4 x 4 meters. Experiment was carried out on November 9, 2006. In each of the plots, planting with 10 grooves with a spacing of 25 cm was made. During the seeding, as per decare 20-20-0 fertilizer with the amount of 5 kg N and 5 kg P_20_5 was used. Two splash cups were placed in each plot. These are described in details elsewhere (Morgan, 1978), but briefly they comprise a hollow cylinder, 10 cm in diameter, pushed into the ground until flush with the soil surface. The tray is partitioned into upslope and downslope compartments. After every rain, only splash detachment was determined. Soil particles splashed from the block of soil isolated in this way are trapped in a circular catching tray, 30 cm in diameter and with a 10 cm high boundary wall. The apparatus catches about 90 percent of the particles detached from the soil in the inner cylinder and exclues a similar percentage of the particles detached from the outside the catching tray (Figure 1). The amount of soil lost due to splash erosion was determined with the help of the following equation.

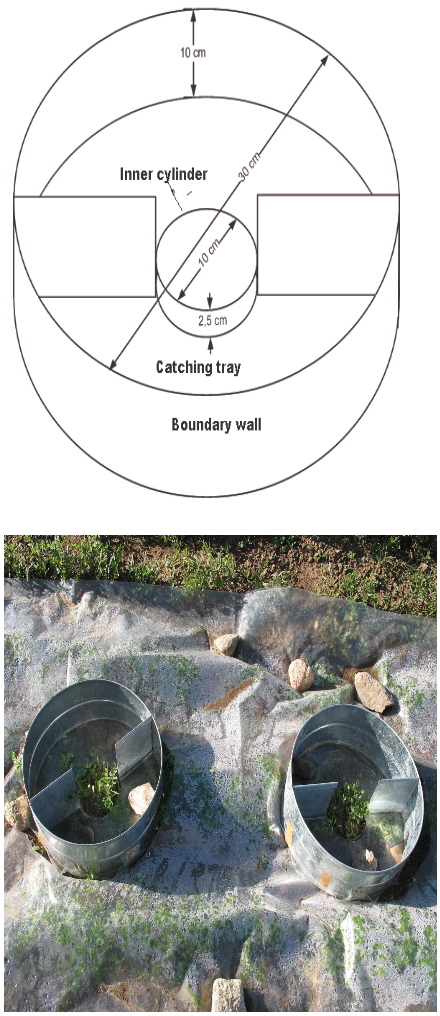

Figure 1. Splash cup used in the experiment

$$D = \frac{M}{A} \qquad (1)$$

In this equation:

D = the amount of soil lost by splashing from unit soil surface (g m^{-2})

Splash amount (M, g) = the amount of soil splashing from the inner cylinder (g)

A = Area of a circle (m^2) (R = 10 cm)

Rainfall intensity and splash detachment measurements were made at three periods between December 16, 2006 and March 25, 2007 (Table 3). Crops are divided into three periods according to their development. The amount of splashed soil in each trap was collected periodically, dried in the oven to constant weight and weighed. Rainfall intensity measurements were made with a rain gauge. Kinetic energy was calculated with the help of using equation (2) with the values of measured rainfall intensity. The kinetic energy (KE), a widely used indicator of the potential ability of rain to detach soil and splash, is related to I as a logarithmic function (Wishmeier and Smith 1978 ; Brandt, 1990):

$$KE\ (J\ m^{-2}\ mm^{-1}) = 210 + 89\ \log_{10}(I) \qquad (2)$$

I= mm h^{-1}

The experiment was terminated on March 27, 2007. Coverage percentages were transferred to the computer by taking photos of 1m x 1m quadrat frames in each soil collection period. Then, the average values of coverage percentages were found.

Data obtained from the research was taken under variance analysis in Minitab 13 for Windows program and evaluated. Significance control of the difference between the average values found was determined by Duncan test.

RESULTS AND DISCUSSION

Splash Erosion

Splash erosion was examined in three periods (Table 3). It was found out that in the first period, effects of slope in splash detachment (p=0.076), plant (p=0.197) and slope x plant interaction were insignificant (p = 0.927). In the second period, slope (p=0.002) and plant effect (p=0.000) were significant, slope x plant interaction was insignificant (p = 0.297). And in the third term, effect of slope (p = 0.001) and plant (p = 0.028) were significant, and slope x plant interaction effect was insignificant (p = 0.077). While splash detachment in 4% slope in the first period was 979.50 g m^{-2}, it became 1532.7 g m^{-2} in 9% slope. However, the difference between these values did not constitute a statistical significance. Splash detachment was observed in the order of from less to more in barley, vetch, ryegrass and control parcel without cover crop. The difference among them was not statistically significant. In the second period from January 25, 2007 to February 15, 2007, splash detachment in 4% slope happened to be 388.48 g m^{-2}, and 784.55 g m^{-2} in 9% slope. Highest splash detachment occurred in the control plot. It was followed respectively by ryegrass, vetch and barley. However, it was placed in the same statistical group. Splash detachment in the third period occurred more 9% slope. Effects of plants occurred just as the same in the second period.

Table 3. Splash detachment in research area (g m^{-2})

	Period1 (December 16, 2006 - January 24, 2007)			Period 2 (January 25 - February 15, 2007)			Period 3 (February 16 – March 25, 2007)		
	Slope		Plant	Slope		Plant	Slope		Plant
Plant	4 %	9%	average	Average	9%	avarage	4%	9%	avarage
Control	1469.6 *±221.30*	2045.9 *±1047.86*	1757.7	943.9 *±156.23*	1366.5 *±325.69*	1155.2**a**	1553.7 *±188.04*	4793.6 *±1794.80*	3173.7**a**
Vetch	846.5 *±224.13*	1357.5 *±190.99*	1102.0	254.8 *±77.25*	639.9 *±120.32*	447.3 **b**	353.5 *±134.52*	467.5 *±244.86*	410.5 **b**
Barley	704.5 *±82.79*	991.7 *±101.27*	848.1	179.0 *±16.33*	271.1 *±38.62*	225.0 **b**	314.4 *±228.57*	210.4 *±56.63*	262.4 **b**
Ryegrass	897.2 *±122.86*	1735.7 *±202.82*	1316.5	176.2 *±54.61*	860.7 *±142.43*	518.5 **b**	222.9 *±90.93*	1431.4 *±91.51*	827.2 **b**
Slope average	979.50	1532.7		388.48 **b**	784.55 **a**		611.10**b**	1725.70 **a**	
p Values									
Slope		0.076			0.002			0.001	
Plant		0.197			0.000			0.028	
Slope x Plant		0.927			0.297			0.077	

Difference between averages shown with different letters is important ($p \leq 0.05$).

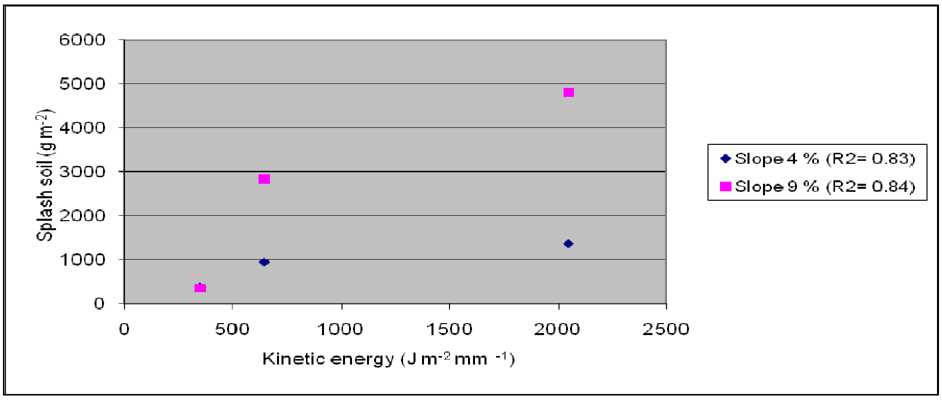

Figure 2. The relationship between splash erosion and kinetic energy (control plots)

Effects of Cover Crops

Although the experiment parcels were exposed to the same cultural processes, amount of splashing soil was affected by slope, crop cover and rainfall properties. Detected cover percentages are given in Table 4. Coverage percentages in the first period occurred as 20% in the ryegrass, 25% in vetch and 33% in barley. In the first period, splash erosion in the control parcel occurred as 1316.5 g m^{-2} for ryegrass, 1102.0 g m^{-2} for vetch and 848.1 g m^{-2} for barley. Crops' cover percentages increased in the second period, and it occurred in vetch, barley and ryegrass as 45%, 60% and 40% respectively. Soil losses in this period occurred as 447.3 g m^{-2} for vetch, 225.0 g m^{-2} for barley and 518.5 g m^{-2} for ryegrass. Coverage percentages in the third period occurred as 75% in the vetch, 80% in barley and 70% in ryegrass. Soil losses in the third period occurred as 410.5 g m^{-2} in vetch, 262.4 g m^{-2} in barley and 827.2 g m^{-2} in ryegrass. In the first period, no differences between splash erosion and crops' coverage rates can be found. As this period is the period in which crops start to grow gradually after coming into the surface of the soil, so their coverage percentages of the soil became close to each other. Hence, splash erosion values became similar to each other. In the second and third periods, crops grew rapidly and increased their soil coverage percentages. Splash erosion decreased in the second period, and it increased in the third period. The amount of rainfall in the third period was almost eight times more than the amount of rainfall in the second period. The fact that no decrease occurred in splash erosion in spite of increase in crop's coverage percentages can be explained with the amount of rainfall. Splash erosion decreased as coverage percentages increased (Table 3). Vegetation protects the soil from splash erosion by intercepting raindrops and absorbing rain drops kinetic energies (Mati 1994). In this case, splash detachment decreases. Vegetation controls soil erosion by means of its canopy, roots, and litter components; erosion also influences vegetation in terms of the composition, structure, and growth pattern of the plant community (Gyssels et al., 2005).

The Effect of Rainfall

Total rainfall amount during the experiment is given in Table 4. The highest amount of total rainfall occurred in the third period (182.6 mm), and the lowest amount of total rainfall occurred in the second period (22.9 mm). As shown in the Table 3, splash detachment occurred as 1155.2 g m^{-2} in the control parcel in the second period which has the lowest amount of rainfall; it rose to 3173.7 g m^{-2} in the third period. In the first period, splash erosion in the control parcel occurred as 1757.7 g m^{-2} under a total amount of 42.2 mm rainfall. Splash erosion increased as the kinetic energy of rainfall increased. Correlation coefficient in control parcels with 9% and 4% slope was determined as 0.84 and 0.83 respectively (Figure 2). Among previous studies of the relationship between rainfall parameters and the amount of soil splashed. Kinnell (1974) found a positive correlation and a linear relationship between the quantity of soil splash and total rainfall when rainfall intensity remained constant. Ellison (1944) reported that the quantity of soil splash increased with drop size, drop velocity and rainfall intensity. Mazurak and Mosher (1968) found that the detachment of soil particles was linearly related to rainfall intensity with uniform size and velocity of raindrops. There was a positive relationship between rainfall intensity and soil splash (Quansah, 1981). Many authors, for instance, Wishmeier and Smith (1958), Morgan (1978), and Al-Durrah and Bradford (1982) found that the kinetic energy of rainfall was the best variable to predict soil splash.

Table 4. During the experiment, crops' cover percentages (%) and total rainfall amount (mm)*

	Period 1 (Dec 16, 2006- Jan 24, 2007)	**Period 2** (Jan 25 - Feb 15, 2007)	**Period 3** (Feb 16 – Mar 25, 2007)
Control	0	0	0
Vetch	25	45	75
Barley	33	60	80
Ryegrass	20	40	70
Rainfall	42.2	22.9	182.6

* Rainfall data were obtained from the Directorate of Meteorology of Çanakkale province.

Many researchers has conducted studies in laboratories indicating the relationship among plant cover, soil loss and rainfall properties (Salles et al 2000; Foot and Morgan 2005). However, few studies have been conducted to illistrate the relationship between splash erosion and plant cover on natural rainfall conditions (Morgan 1978; Mati 1994). Under natural rainfall conditions, factors such as soil water, soil seal mechanisms, cycles of wetting and drying affect splash detachment (Wakiyama et al 2010).

CONCLUSION

Splash erosion generally showed increase with the rise in the slope. The effect of crops used in the experiment on splash erosion was similar. Plant cover played a protective role against splash erosion. The lowest splash detachment among the crops used in the experiment observed in barley. Splash erosion increased as the rainfall increased in the control parcels. In order to explain this effect, further detailed researches explaining the relationships of raindrop size distribution, rainfall intensity and kinetic energy of rainfall with plant cover at natural slopes, are necessary.

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