J. Agric. Sci. Mansoura Univ., 29 (10): 5965 - 5971, 2004

THE RATE OF WATER EROSION AND ITS RELATION TO SOIL COVERAGE BY GRAVEL AND NATURAL VEGETATION

Ali, A. A.; S. F. T. Sharkawy and M. M. Wassif
Soil Cons. Dept., Desert Res., Mataria-Cairo, Egypt

ABSTRACT

Two Field experiments were carried out in Wadi-Maged, west Matrouh city, North Western Coastal Zone of Egypt (NWCZ), under natural rainfall conditions, during winter seasons 2001-2002 and 2002-2003, to evaluate the rate of water soil erosion under different percentages of gravel or natural vegetation cover. Soils of Wadi-Maged are mainly sandy loam in texture with shallow profile.

Soil cover by gravel or natural vegetation showed great potential for erosion control on sloped area. The obtained results revealed that the depths of natural rainfall through the two successive winter seasons were 123.1 and 118.3mm. The lowest runoff value and amount of soil loss were observed for 25% natural vegetation cover and 20% gravel mulch treatments. The average annual soil loss was 4.87ton.ha^{-1} for bare soil treatment, while it reaches 2.41ton.ha^{-1} for 25% vegetation mulch treatment. The average annual soil losses were 2.81, 2.17 and 1.59ton.ha^{-1} for 5, 10 and 20% gravel mulch of the soil surface, respectively. Leaving natural vegetation and gravels at 25 and 10%, respectively, on the surface of cultivated slopped soils in NWCZ areas led to decrease runoff and soil loss (wash erosion) values by approximately 50%. Data indicate that the significant relationship between average annual soil loss (Y, ton.ha^{-1}) or average annual runoff (Y, mm) and soil cover by gravel (X, %) are fitted with the exponential equation: ($Y=ab^X$).

The results from this study demonstrate the extreme variability of erosion measurements. This variability severely limits the usefulness of the data for determining percentage of soil surface coverage needed to achieve a given level of erosion control. Further studies are needed to define the relationship between soil cover by natural vegetation and soil loss under the NWCZ conditions, Egypt.

Keywords: Water erosion, rainfall, runoff, soil loss, natural vegetation, gravel, North Western Coast Zone of Egypt (NWCZ)

INTRODUCTION

Water from the raindrops that fall in a storm event can be both useful and damaging. While it may also be a primary source of energy for soil erosion by water, the extent of soil erosion by water may be influenced by the rainfall characteristics, plant cover and management practices than by the inherent properties of the soil. Water erosion is controlled in one or both of two ways: (1) reduce the erosive agent's energy (i.e., raindrop impact and runoff) or (2) increase the soil's resistance to detachment. The second way is long term and highly desirable, but its impact is usually less than that of the first. Maintenance of cover in contact with soil is the most effective single factor reducing erosion. *Wischmeier and Smith (1978)* found that 90% mulch cover would cut erosion by 93%. This type of soil management reduces the energy of both raindrop impact and runoff.

In Egypt, the rainfed agriculture is concentrated in The NWCZ where barley and wheat are the main crops. In such areas, not only the average rainfall is low but also its distribution during the growing season is often poor. *Meyer and Mannering (1963)* and *Meyer et al. (1970)* stated that crop residue mulches effectively control agricultural erosion, and straw mulches have been used successfully on many construction sites. They also reported that stone and gravel mulches control soil erosion. *Zuzel and Pikul (1993)* have suggested that mulch cover greater than about 30% provide greater erosion reduction effectiveness than that indicated by *Wischmeier and Smith (1978)*. Other studies have indicated that straw mulch cover of 30% provide no erosion protection when compared with bare soil plots. In addition, *McGregor et al (1988)* did not agree with the study carried out *by Wischmeier and Smith (1978)*.

The *United Nations (1992)* reported that, the semiarid areas surrounding the Mediterranean Sea is seriously affected by soil degradation and desertification. Water erosion is the main degradation process, while human pressure, the reduction of plant cover, and the nature of the parent material are the main causes of soil erosion.

MATERIALS AND METHODS

Two field experiments were conducted in two-winter seasons (2001-2002) and (2002-2003) at Wadi-Maged, NWCZ of Egypt. Wadi-Maged is located west Matrouh city. The slope of the experimental site is 7% in south - north direction.

Universal soil loss equation plots (22.1 x 2.1m) were used to measure soil loss and runoff using Gerlesh trough (0.5m long and 0.2m wide), *FAO (1993)*, at the end of slope. The treatments were as follow: bare soil (no mulch), natural vegetation covers about 25% of the plot area, and gravel mulch at the rate of 5, 10 and 20% of the plot area. Percentages of natural vegetation cover and gravel mulch cover were determined according to *Fryrear et al. (1998)*. Three replicates were conducted for each treatment.

Some properties of the investigated soil were determined according to *FAO (1970)* and *Page et al. (1982)*. Mulch factor for each condition of soil cover was calculated as the ratio of total soil loss from the covered plot to the total soil loss from bare plot (soil loss ratio, SLR).

RESULTS AND DISCUSSION

Field experiments were conducted in two successive winter seasons at Wadi-Maged, El Qasr area at Mersa Matrouh governorate. Some soil physical and chemical properties of the experimental site are given in Table (1). The soil is sandy loam in texture with shallow profile. $CaCO_3$ content is 11.9%. The bulk density is $1.5 g.cm^{-3}$. Also, the data indicate that the soil is non-saline - non-alkaline.

Table (1) some soil properties of the experimental site.

Soil depth(cm)	p^H	E.C ($dS.m^{-1}$)	$CaCo_3$ (%)	Bulk density ($g.cm^{-3}$)	Particles size distribution (%)				Texture class
					Coarse sand	Fine sand	Silt	Clay	
0 – 20	7.8	1.2	11.9	1.5	32.5	35.8	13.6	18.1	S.L*
20 – 40	7.8	1.3	15.4	1.55	24.7	43.7	12.4	19.2	S.L*

* S.L.: Sandy Loam

Rainfall characteristics:

Total precipitation is recorded daily using the automatic rain gauge during the study periods for the experimental site and the values are given in Table (2). The total depth of rainfall in the first season was 123.1mm, while in the second one it was 118.3mm. The average annual rainfall for both seasons was 120.7mm.year^{-1}. The highest rainfall events occurred on 5/12/2001 and 22/1/2003 where 23.8 and 25.7mm of rainfall were recorded, respectively. Twenty-three storms occurred during the study period. Five storms were effective in the first season and four storms were effective in the second one as they caused runoff and consequently soil loss.

Data in Table (2) indicated that the effective storms (storm, with rainfall depth more than 10mm and intensity more than 3.2mm.hr^{-1}) caused runoff from all treatments. The total depth of the effective storms was 82.5mm in the first season, and 70.6mm in the second one. Rainfall intensities of the effective storms ranged between 3.2 and 7.6mm/hr during the study periods. The rainfall depths for the effective storms represented 63.4% of the total rainfall during the two studied winter seasons.

Surface runoff:

Runoff depths are presented in Table (2). Data indicate that runoff increased with increasing rainfall intensity for all treatments during the study periods. The highest runoff losses were measured for bare soil treatment. The total depths of runoff obtained from bare soil treatment reached 4.67 and 4.06mm for the two studied winter seasons, respectively, indicating that the average runoff coefficient approaches 3.62%. These findings are in agreement with those for *Viertman (1989) and Ali et al. (2002),* they mentioned that under the conditions of NWCZ, the runoff coefficient of 3% is seen reasonable. The increase in surface runoff in the first season was attributed to the characteristics of rainfall events. The reduction percent in the total depth of runoff for different conservation treatments varied from 27.6 to 69.8% for the first season, and from 25.1 to 71.4% for the second one. Similar results were obtained by *FAO (1993)*, which mentioned that mulch cover reduces erosion and protects soil against degradation.

Table (2) Effect of soil coverage on runoff for Wadi-Maged area.

Date	Rainfall			Runoff (mm)				
	Depth (mm)	Duration (hr)	Intensity ($mm.hr^{-1}$)	Bare soil	Natural vegetation cover (25 %)	Gravel cover (5%)	Gravel cover (10%)	Gravel cover (20%)
2/11/2001	10.20	3.20	3.19	0.70	0.38	0.48	0.36	0.19
5/12/2001	23.80	3.40	7.00	1.30	0.60	0.87	0.68	0.35
17/12/2001	7.60	1.50	5.07	-	-	-	-	-
27/12/2001	8.40	4.20	2.00	-	-	-	-	-
2/1/2002	6.20	3.40	1.82	-	-	-	-	-
5/1/2002	5.20	2.50	2.08	-	-	-	-	-
7/2/2002	16.20	3.80	4.26	0.95	0.46	0.68	0.52	0.29
17/2/2002	13.60	3.70	3.68	0.73	0.43	0.63	0.46	0.26
3/3/2002	8.60	2.40	3.58	-	-	-	-	-
20/4/2002	4.60	5.30	0.87	-	-	-	-	-
Total	123.1	-	-	4.67	2.36	3.38	2.56	1.41
6/11/2002	11.30	2.50	4.52	0.71	0.32	0.51	0.35	0.19
1/12/2002	8.80	6.00	1.47	-	-	-	-	-
10/12/2002	8.30	4.00	2.08	-	-	-	-	-
1/1/2003	22.80	3.20	7.13	1.20	0.64	0.92	0.66	0.34
7/1/2003	1.90	2.00	0.95	-	-	-	-	-
22/1/2003	25.70	3.40	7.56	1.50	0.79	1.10	0.83	0.46
5/2/2003	8.10	2.50	3.24	-	-	-	-	-
13/2/2003	7.20	2.50	2.88	-	-		-	-
15/2/2003	5.40	4.20	1.29	-	-	-	-	-
10/3/2003	3.20	3.00	1.07	-	-	-	-	-
17/3/2003	10.80	2.60	4.15	0.65	0. 30	0.51	0.32	0.17
2/4/2003	4.80	4.10	1.17	-	-	-	-	-
Total	118.30	-	-	4.06	2.05	3.04	2.16	1.16
Av.year^{-1}	120.70	-	-	4.37	2.21	3.21	2.36	1.29

The natural vegetation mulch treatment reduced runoff. Table (2) reveals that 25% vegetative cover reduces average annual runoff by 49.5% relative to bare soil treatment. *Meyer et al. (1970)* obtained similar results; they mentioned that the application of 0.56metric ton.ha^{-1} mulch decreased soil erosion to one third of that from unmulched treatment.

The data in Table (2) reveal the relative effectiveness of soil mulching with gravel on reducing the rate of soil erosion under the condition of Wadi-Maged. According to cover percent with gravel, the depths of surface runoff are arranged in the following descending order: bare soil without gravel cover >gravel cover 5% > gravel cover 10% >gravel cover 20%, respectively. On the base of average, conservation treatments with respect to the reduction of surface runoff depth, is arranged in the following descending order as follows: gravel cover 20% > natural vegetation cover 25% > gravel cover 10% > gravel cover 5%, respectively. *Renard et al. (1974)* reported that pavements reduced erosion under desert conditions. Where plant cover is limited, gravel covered surfaces are very effective in absorbing the impact energy of raindrops. *Stewart and Moldenhauer (1994*) stated that the principle for controlling water erosion include minimizing the impact of raindrops on the soil surface, increasing infiltration rate, and minimizing the distance that surface water can travel.

Average annual runoff began to be a function of the percentage of soil surface cover by gravel. Simple correlations coefficient and regression equations were used to evaluate such function during the study periods. Data in Table (2) reveal that the exponential regression equation was fitted to the experimental data as follows: $Y = 4.36(0.94)^X$, where Y: average annual depth of surface runoff (mm) and X: percentage of soil surface cover by gravels. The exponential regression equation had high correlation coefficient value (-0.999) at 1% significant level. *FAO (1993)* reported that several authors under different types of vegetation cover have suggested exponential relationship between runoff value and mulch rates.

From the preceding data, the average reduction efficiency for water soil erosion from soil conservation treatments ranged between 26.4 and 70.6%. Gravel and natural vegetating covering by 10 and 25% of the soil surface reduced runoff value by 46 and 49%, respectively, compared with bare soil treatment. Therefore, the presence of gravel and natural vegetation, at least with 10 and 25%, on the soil surface helps to minimize water soil erosion hazards.

Soil loss:

With respect to the effect of applied soil mulching treatments on the amount of soil loss by water erosion, data in Table (3) show that the total amounts of transported soil solid constituents were 5.26 and 4.47 $ton.ha^{-1}$ for bare soil treatment for two seasons, whereas such losses from the natural vegetation cover treatment were 2.68 and 2.13$ton.ha^{-1}$ in the first and second season, respectively. Data in Table (3) also reveal that the total amounts of soil losses from gravel mulch treatments were 3.15, 2.41 and 1.79$ton.ha^{-1}$ for the first season, while for the second season, it reached 2.47, 1.93 and 1.39$ton.ha^{-1}$. For reducing soil erosion, the indirect effects by natural vegetation or gravels reduced both soil erodibility and kinetic energy of raindrops. Consequently, soil cover by 25% natural vegetation or by gravels from 5 to 20% reduces wash erosion. *Govers and Poesen (1988*) observed that the positive effect of 0.250 and 1.12$metricton.ha^{-1}$ soil mulch on reducing soil loss for all particle size classes.

Soil loss as a function of percent cover was derived using regression equations. Only the exponential equation had a significant correlation coefficient at 5% significant level (r = - 0.95). Data in Table (3) reveal that the fitted exponential equation between average annual soil loss (Y, $ton.ha^{-1}$) and percentage of soil surface cover by gravels (X, %) was as follows: $Y = 4.16 (0.95)^X$. *Laflen et al. (1983) and Gregory (1982)* obtained similar results. They reported the presence of a negative exponential relationship between soil loss and the mean value of vegetation cover.

From the preceding data, the average reduction efficiency for soil loss by water erosion due to soil conservation treatments ranged between 42 and 67%. Gravel and natural vegetating covering of 10 and 25% of the soil surface helps to reduce soil loss values by 55 and 51%, respectively, compared with bare soil treatment. Therefore, the presence of gravel and natural vegetation at least 10 and 25%, respectively, on the soil surface will help to combat water soil erosion hazards.

It can be concluded that leaving at 25 and 10% natural vegetation and gravels on the surface of cultivated slopping soil on the NWCZ areas will lead to decrease runoff and soil loss (wash erosion) values by approximately 50%. It should also be stated that the surface cover factor (C) included in the calculation of the universal soil loss equation (USLE) for the NWCZ of Egypt should be the values of soil loss ratios obtained from this investigation rather than recommended ratios by Wischmeier and Smith (1978).

Table (3) Soil Loss ratio affected by different types of soil cover.

Storm date	Rainfall depth (mm)	Rainfall intensity ($mm.hr^{-1}$)	Soil loss ($ton.ha^{-1}$)				
			Bare soil	Natural vegetation cover (25%)	Gravel cover		
					(5%)	(10%)	(20%)
2/11/2001	10.20	3.19	0.64	0.30	0.38	0.29	0.17
5/12/2001	23.80	7.00	1.52	0.80	0.86	0.62	0.49
7/2/2002	16.20	4.26	1.04	0.52	0.63	0.50	0.40
17/2/2002	13.60	3.68	0.86	0.46	0.54	0.45	0.30
19/3/2002	18.70	5.84	1.20	0.60	0.74	0.55	0.43
Total	82.50	-	5.26	2.68	3.15	2.41	1.79
6/11/2002	11.30	4.52	0.88	0.34	0.42	0.34	0.20
1/1/2003	22.80	7.113	1.37	0.71	0.78	0.64	0.49
22/1/2003	25.70	7.56	1.55	0.74	0.87	0.66	0.50
17/3/2003	10.80	4.15	0.67	0.34	0.40	0.29	0.20
Total	70.60	-	4.47	2.13	2.47	1.93	1.39
Av.$year^{-1}$	76.55	-	4.87	2.41	2.81	2.17	1.59
Soil loss ratio	-	-	-	0.49	0.58	0.45	0.33

REFERENCES

ALi, A. A.; S. F. T. Sharkawy and M. M. Wassif (2002). Soil erosion by rainfall in North Western Coastal Zone, NECZ, of Egypt. National Symposium on Problems of Land Degradation in Egypt and Africa, Institute of African Research & Studies. Cairo University, 23-24 March 2002.

FAO (1970). Physical and Chemical Properties of Soil and Water Analysis. Soils Bull. No (10). FAO Publ. 61, Rome, Italy.

FAO (1993). Field Measurement of Soil Erosion and Runoff. Soils Bull. No (68). Rome, Italy.

Fryrear, D. W.; A. Saleh; J. D. Bilbro; H. M. Schomberg; J. E. Stout and T. M. Zobeck (1998). Revised Wind Erosion Equation (RWEQ). Wind Erosion and Water Consevation Research Unit. USDA-ARS, Southern Plains Area Cropping Systems Research Laboratory. Technical Bulletin No. 1.

Govers, G. and G. Poesen (1988). Assessment of the interrill and rill contributions to total soil loss from an upland field plot. Geomorphology, 1: 343-354.

Gregory, J. M. (1982). Soil cover prediction with various amount and types of crop residues. Trans. of ASAE, 25 (5): 1333 -1337.

Laflen, T. M.; G. R. Foster and C. A. Onstad (1983). Simulated of individual-storm soil loss for modeling the impact of soil erosion in productivity. pp285-295 in Soil Erosion and Conservation. Soil Conservation Society of America, By I. A. Ankeny.

McGregor, K. C.; R. L. Bengston and C. K. Mutchler (1988). Effect of surface straw on interrill runoff and erosion of Granada silt loam soil. Trans. of ASAE, 31:111-116.

Meyer, L. D. and J. D. Mannering (1963). Crop residue as surface mulches for controlling erosion on sloping land under intensive cropping. Trans. of ASAE: 322-327.

Meyer, L. D.; W. H. Wischmeier and G. R. Foster (1970). Mulch rates required for erosion control on steep slopes. Soil Sci. Soc. Am. Proc. 34: 982-1991.

Page, A. L.; Miller R. H. and D. R. Keeny (1982). Methods of Soil Analysis. Part 2, No. 9 Agronomy Series, Amer. Soc. of Agron. Madison, Wis., USA.

Renard, K. G.; J. R. Simanton and H. B. Osborn (1974). Applicability of the universal soil loss equation to semiarid rangeland conditions. P: 18-32 in Hydrology and Water Resources in Arizona and the Southwest. Vol. (4). Univ. of Arizona, Tucson.

Stewart, B. A. and W. C. Moldenhauer (1994). Crop residue management to reduce erosion and improve soil quality. Conservation Research Report, No. 37. USDA-ARS, USA.

United Nations (1992). The Environment in Europe and North America; Annotated Statistics 1992. United Nations Publ., New York.

Viertman, W. (1989). Report on Qasr Rural Development Project. Matrouh Governorate, Egypt.

Wischmeier, W. H. and D. D. Smith (1978). Predicting Rainfall Erosion Losses. A Guide to Conservation Planning. Agric. Hand Book No. 537, USDA. GOV. Print. Washington, D.C.

Zuzel, J. F. and J. L. Pikul (1993). Effect of straw mulch on runoff and erosion from small agricultural plots in Northeastern Oregon. Soil Sci. 156 (2): 111-117.

معدل الانجراف بالمياه وعلاقته بتغطية التربة بالحصى و النبات الطبيعي

علاء الدين عبد الفتاح على، سعد فوزي تادرس شرقاوي، محمد محمد وصيف
قسم صيانة الاراضى- مركز بحوث الصحراء- المطرية –القاهرة – مصر

نفذت تجربتان حقليتان في وادي ماجد، غرب مدينة مطروح، منطقة الساحل الشمالي الغربي بمصر، تحت ظروف المطر، خلال مواسم شتاء ٢٠٠١-٢٠٠٢ و ٢٠٠٢-٢٠٠٣ لتقييم معدل انجراف التربة بالمياه تحت النسب المئوية المختلفة لتغطية سطح التربة من الحصى و النبات الطبيعي.تتصف تربة وادي ماجد بقوام طمي رملي .ات قطاع ضحل.

النتائج المتحصل عليها دلت على أن كمية المطر خلال فصلي الشتاء المتعاقبين كانتا ١٢٣,١ و ١١٨,٣ ملليمتر .القيم الأقل لكل من ماء الجريان السطحي وفاقد التربة قد لوحظت فى معاملة تغطية سطح التربة بمعدل ٢٥% من النباتات الطبيعية و ٢٠% من الحصى .كان متوسط فاقد التربة السنوية ٤,٨٧ طن/ هكتار لمعاملة التربة الغير مغطاة (الكنترول)، بينما بلغ متوسط فاقد التربة السنوي ٢,٤١طن /هكتار لمعاملة التغطية بمعدل ٢٥% من النباتات الطبيعية . كانت المتوسطات السنوية لفاقد التربة ٢,٨١، ٢,١٧و ١,٥٩ طن /هكتار لمعاملات التغطية بالحصى بمعدلات ٥، ١٠ و ٢٠% على التوالي. إن ترك النباتات الطبيعة والحصى على الأقل بمعدل ١٠ و ٢٥% على التوالي، على سطح الاراضى المائلة في منطقة الساحل الشمالي الغربي يؤدى إلى نقص معدلات ماء الجريان السطحي و فاقد النربة بـ ٥٠% تقريبا .تشير البيانات إلي أن العلاقة المعنوية بين متوسط فاقد التربة السنوية (Y، طن /هكتار) و متوسّط ماء الجريان السطحي السنوي (Y، ملليمتر) والتغطية بالحصى لسطح التربة (X ,%) هي آسية ($Y = a b^X$).:

تعرض نتائج هذه الدّراسة إلى ان كميات المواد المنجرفة شديدة التغير .هذا التّغيّر يحدّد بشدة من فائدة تقدير النسبة المئوية لتغطية سطح التربة المطلوبة لتحقيق مستوى المقاومة للسيطرة على الانجراف .المطلوب هو أجراء دراسات أخرى لتحديد العلاقة بين غطاء سطح التربة بالنّبات الطّبيعي وفاقد التربة تحت ظروف منطقة الساحل الشمالي، مصر.