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Sediment Transport Experiments: The Influence of the Furrow Geometry

S. Haddad and M. Bouhadef

Abstract**—**In this experimental work, we have shown that the geometric shape of the grooves (furrows) plays an important role in sediment dynamics. In addition, the rheological behaviour of solid discharge does not depend only on the velocity discharge but also on the geometric shape.

Keywords**—**Laboratory experiments, soil erosion, groove, furrow, sediment transport

I. Introduction

EACH year, more than 120 million tons of lands are torn by the erosion of Algerian mountain slopes. This large amount of lost land is mainly the result of irrational use of agricultural land and poor farming practices ([1], [2] and [3]). Surface irrigation furrow is widely used in Algeria in view of its simplicity and economy. It is suitable for many crops: vineyards, orchards and trees ([4], [5] and [6]). According to the Algerian Ministry of Agriculture, the use of furrows on slopes greater than 12% is quite common.

The grooves can have different agricultural geometric shapes: triangular, trapezoidal, rectangular or parabolic with widths varying between 15cm and 75cm and depths from 10 cm to 20 cm. Contrary to their simplicity and efficiency, the channels can easily become the site of severe erosion problems once the slope exceeds 1% ([4], [5] and [6]).

The literature gives six factors responsible for the erosion: slope, size, velocity, time of watering, vegetation and the length ([7], [8], [9] and [10]). To these factors, it is necessary to add the likely effects of the explosion of air stored in the soil layers and the electrical double layer [11].

In the 1940 and 1950's years, the work of E. W. Lane focused on finding the best geometric profile which can be stable, that is to say, without erosion or deposition ([12] and [13]). It is true that the works of E. W. Lane were referred to the major irrigation canals. V. T. Chow, in his monumental book "Open Channel Hydraulics" noted that the distribution of shear stress was independent on the size of the cross section of the channel [14]. It is therefore logical to think that the shape of the cross section of the grooves may influence the sediment transport.

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II. Experimental Model

The soil that we used in our experimental investigation was taken from the first 30 cm of soil belonging to the Algerian agricultural plain Abadla (Figure 1).

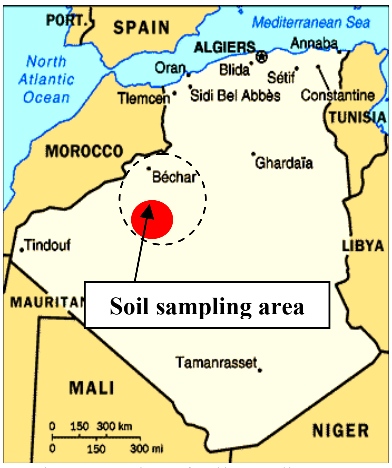


Fig. 1 Location of soil sampling area

The amounts collected were placed in plastic bags and transported to the laboratory. Testing particle size, physicochemical and mechanical properties were performed.

TABLE I
PARTICLE SIZE CHARACTERISTICS

A	L F	L G	S F	S M	S G
19%	10%	6%	47%	7%	11%
D_{Ap}	D_r	Po	Ac	pH (sol)	K
1,41	2,969	0,47	1,2	8,2	27 mm/h

A	Clay	Ac	Clay Activity
L F	Fine silt	K	Permeability
L G	Coarse silt	Po	Porosity
S F	Fine sand	D_{Ap}	Absolute density
S M	Medium sand	D_r	Relative density
S G	Coarse sand		

The table shows that the soil is a fine sandy loam [15]. From the mechanical point of view, the soil is clay type inorganic low to medium plasticity. Activity Index (Ac) of about 1.2 indicates that the clay type kaolinite with low swelling capacity.

All tests were performed on an experimental model (Figure 2) manufactured completely in galvanized steel plate 3mm thick. The model has a form of rectangular channel of length x width x depth equal 2000 x 150 x 120 mm. 3mm diameter holes were provided, on both sides and the bottom of the model, to ensure a free flow underground. The downstream part is equipped with a system of rotation of the model. The upper part is equipped with a manual hydraulic jack for lifting the model. Within the model, system, honeycomb is arranged to ease the flow of water and make them uniform before entering inside the model. For the collection of volumes of clean water and mixture, the plastic bowls were placed on the floor.

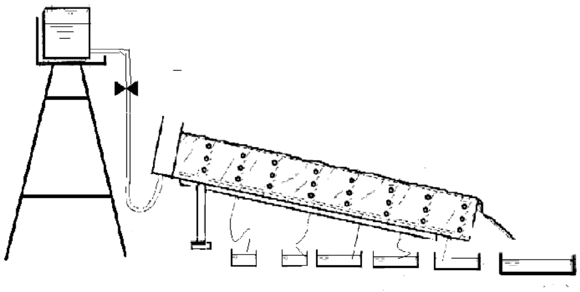


Fig. 2 General scheme of the experimental model

III. Soil Preparation

Before placing the soil, naturally ventilated, it is passed through a screen mesh 3 x 4 mm. After that, we add the amount of water that provides the desired percentage of moisture and the whole is mixed to obtain good homogenization. Following this step, the wet mixture is passed a second time through the same sieve before. This phase is important because it eliminates the aggregates that formed after adding water and mixing. After that, we cover the inside of the experimental model with a sheet of 5mm thick sponge to act as a drain filter.

Before starting the phase of the implementation of the ground, it is useful that the model is horizontal. The soil is placed inside the model in layers 5 cm thick. After gently leveled with a wooden spatula, soil compaction is subjected to free-fall from a height of 30 cm with a mass of 15kg on a flat sheet steel of 65 x 14 cm placed above the ground ([16] and [17]). The same procedure is repeated up to a soil depth of 10 cm.The soil is prepared and the shape of each agricultural groove is carried out using an appropriate metal tool. There are as many tools as forms of furrows. These small tools are the reduced forms of real hoes used by farmers (Figure 3)

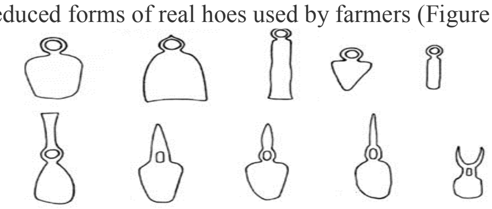


Fig. 3 Different types of hoes used in agriculture

Once the furrow dug, the model is moved, using a cylinder, to obtain the desired slope. The experimental model is then supplied with the first flow of water for a relatively short time of 2 minutes. This time of runoff has been chosen following the work of T.J Trout and J. A. Gomez who concluded that sediment transport and runoff follow linear laws in the first few minutes ([7], [10] and [16]). After this time, the power is off and we take photographs.

The mixture is set for 6 hours to facilitate settling and to separate the solid from the liquid phase. After settling, there should be a first weight of the liquid extracted. The solid phase, sip of water, is put in the oven for 24 hours. After that, a second weighing will give the actual mass of sediment exported from the furrow.

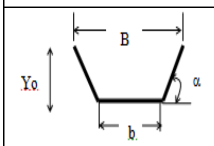
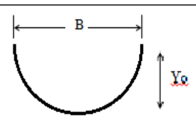
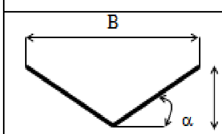
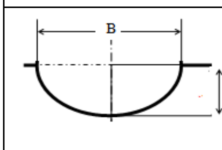
IV. Experimental procedure

This experimental work aims to study the influence of the geometric shape of the grooves on the agricultural rate of sediment transport and rheological nature of the solid discharge. It is useful to note that in all series of experiments, two factors only change: the geometric shape of the grooves and the slope of the channel. In this study, we chose four kinds of slots and 3 slopes. We considered the circle, trapezoid, triangle and sine. For the slopes, we chose 1%, 20% and 52%.

The geometric characteristics of the grooves were obtained after studying the laws of similarity of flows with moving bottom ([18] and [19]).

The final dimensions of the different types of grooves are given in the table below (Table IV).

Table II
Geometrical characteristics of the grooves

Form of groove	Function	Parameters
		Yo = 3.2 cm B = 7.3 cm b = 2.6 cm α = 54°
	$x^2 + y^2 = (3.2)^2$	Yo = 3.2 cm B = 6.4 cm b = 0
		Yo = 3.2 cm B = 9.5 cm b = 0 α = 34°
	$3{,}2 \sin \frac{\pi . x}{10}$	Yo = 3.2 cm B = 10 cm b = 0

V. Results

Table V gives the results of experimental measurements for each form of the groove.

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TABLE III
SEDIMENT MASS EXPORTED

	Slope = 1%	Slope = 20%	Slope = 52%
Form	**Mass (g)**	**Mass (g)**	**Mass (g)**
Sine	41.19	2178.90	9149.06
Triangle	93.15	3462.30	6464.39
Trapezoid	870.48	5547.48	7606.91
Circle	192.28	4233.29	4967.55

The reading of this table allows the following remarks:

- The mass of sediment varies greatly with slope.
- The mass of sediment varies greatly with the shape of the groove.

VI. DISCUSSION

A. Effects of the shape on the sediment transport

The shape of the grooves was never considered as a factor involved in sediment dynamics in agricultural furrows. The chart above and photos below show clearly that the shape of the groove strongly influences sediment dynamics. Indeed, for slopes less than 32%, the sinusoidal shape involves less sediment transport, followed by the circle, then the triangle and finally the trapezoid shape.

In the other hand, for slopes greater than 45%, the best form is the circle, followed by the triangle, trapezium and finally the sine.

Sine (52 %) Sine (20 %)

Fig. 4a Types of erosion for sinusoidal groove

Circle (52 %) Circle (20 %)

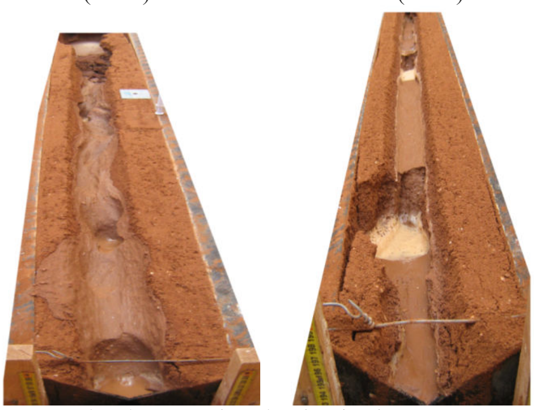

Fig. 4b Types of erosion for circular groove

B. Effect of the shape on the rheological behavior of mixture

The experiments also led to the fact that rheological nature of the solid discharge depends not only on the value of the volume concentration Cv but also the geometric shape of the groove (furrow) [15]. Figure 5 clearly shows that:

- For the trapezoidal shape, the fluid becomes non-Newtonian when the slope *p* is greater than 9%.
- For the circle, this occurs for p greater than 16%.
- For the triangle shape, the fluid is non Newtonian as soon as the slope is greater than 20%.
- For the sine shape, the limit is higher since p is greater than 27%.

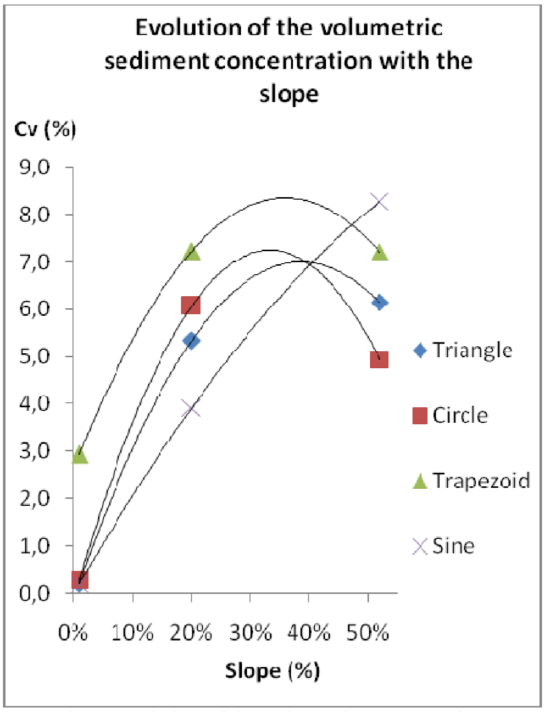

Fig. 5 Evolution of the volumetric concentration

VII. CONCLUSION

After these series of experiments, we can conclude that the geometric shape of the agricultural grooves strongly influences sediment dynamics. For models that predict sediment transport in agricultural furrows, the introduction of a geometric shape parameter seems essential. Moreover, our experiments showed that the rheological solid discharge characteristics depend not only on the volumetric concentration Cv sediment but also with the geometric shape.

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REFERENCES

[1] M. Mezali, “Forum des Nations Unies sur les Forets. Quatrième session – Rapport National,” Ministère de l’Agriculture et du Développement Rural. Direction Générale des Forêts, Alger 04 Novembre, 2003.

[2] Agence Nationale d'Aménagement du Territoire, “Schéma National d’aménagement du territoire,” Ministère de l’Aménagement du Territoire et de l’Environnement, Algérie, 2004.
[3] Direction Générale des Forets, "Journée internationale de la montagne", Ministère de l’Agriculture et du Développement Rural, Algérie, 2007.
[4] United State Department of Agriculture, “Irrigation guide,” National Engineering Manual, 1997.
[5] C. Brouwer, “Irrigation Water Management - Irrigation Methods – Training manual no 5,” FAO . Rome, 1988.
[6] C. M. Burt, A. J. Clemmens, R. Bliesner, J. L. Merriam, and L. Hardy, “Selection of irrigation methods for agriculture,” American Society of Civil Engineers. 1801 Alexander Bell Drive Reston, Virginia 20191-4400, 1999.
[7] T. J. Trout, “Furrow irrigation and sedimentation: On – field distribution,” American Society of Agricultural Engineers., vol. 39(5), pp. 1717-1723, 1996.
[8] D. L. Carter, and D. E. Miller, “STEEP – Conservation Concepts and Accomplishments,” Washington State University Publication, Pullman, Washington., pp. 585 – 591, 1987.
[9] R. D. Berg, and D. L. Carter, “Furrow erosion and sediment losses on irrigated cropland,” Journal of Soil and Water Conservation., vol. 35, no. 6, 1980.
[10] T. J. Trout, “Sediment transport in irrigation furrows,” 10 th International Soil Conservation Organization Meeting held May 24-29 at Purdue University and the USDA-ARS National Soil Erosion Research Laboratory, 2001.
[11] B. B. Goossak, “On the mechanism of the erosion under furrow irrigation,” Assemblée Internationale d’Hydrologie Scientifique. Assemblée générale de Helsinki, Publication N° 53 de l’Association Internationale d’Hydrologie Scientifique, 1960.
[12] E. W.Lane, “Principles of design of stable channels in erodible material,” Report No. HYD 293. United States Department of Interior. Bureau of reclamation, 1950.
[13] A. C. Carter, and E. W. Lane, “Distribution of tractive forces around channel perimeters,” Report No. HYD 307. United States Department of Interior. Bureau of reclamation, 1950.
[14] V. T. Chow, “Open Channel Hydraulics,” McGraw – Hill International Book Company. New York, 1959.
[15] FAO, “Guidelines for soil description,” Rome, 2006.
[16] J.A. Gomez, and M.A. Nearing, “Runoff and sediment losses from rough and smooth soil surfaces in a laboratory experiment,” Catena, no. 59, pp. 253-266, 2005.
[17] M.J.M. Romkens, K. Hemling, and S.N. Prassard, “Soil erosion under different rainfall intensities, surface roughness, and soil water regimes,” Catena, no. 46, pp. 103-123, 2001.
[18] F. M. Henderson, “Open Channel Flow,” MacMillan Company: New York, USA, 1966.
[19] H. Chanson, “The Hydraulic of Open Channel: An Introduction,” 2nd Butterworth-Heinemann, Oxford, 2004.
[20] P. Y. Julien, “Erosion and sedimentation,” Cambridge University Press. New York, 1995.