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LABORATORY EXPERIMENT: THE EFFECT OF THE OVERLAND FLOW HYDRAULIC PARAMETERS ON SEDIMENT CONCENTRATION

Soil water erosion occurs through a combination of the detachment and transport of soil particles by erosive agents such as splash, the flow of surface induced by rain or both. *Kinnell 2000; Lu et al. 2015; Guo et al., 2015* suggest that the erosion process of sloping soils is strongly influenced by the characteristics hydraulic surface flows (flow regime, flow depth, flow velocity, shear stress, power and friction). The runoff can take various forms, from runoff to a very thin layer of surface surface overland flow up to heavily drained concentrated in the rills, even gullies, caused by erosion. The objective of this study was to try to find the influence of the hydraulic parameters on sediment concentration. To overcome this study, an experimental study is carried out in the laboratory using a rainfall simulator. This study was conducted on a remolded agricultural soil collected from the ITCMI Algiers (Technical Institute of Industrial Vegetable Crops)), exposed first to a series of simulated rainfall intensities ranging from 30 mm.h^{-1} to 100 mm.h^{-1}; then the same soil, was subjected to the action of rainfall and surface runoff, with a constant flow rate which forms a water layer on the soil surface. That allowed us to find that the effect of the overland flow on sediment concentration is very significant.

***Keywords*: rainfall simulator; rainfall intensity; runoff; sediment concentration; flow regime.**

1. Introduction :

The main variables that control the action of the runoff from the detachment and transport of particles are the slope, flow velocity and flow thickness (*Gimenez and Govers, 2002*). The redistribution of particles does not necessarily promote the flow. It has been suggested that, under certain conditions (in particular slope), flowing water erodes the crusts it previously formed. Setting earth fragments motion by the impact of raindrops is a process that takes place both on a free soil surface than in a thin sheet of water (*Green and Houk, 1980; Moss and Green, 1983*). Several mechanisms are suggested to explain this set in motion: either joint training of soil particles with the splash ring is an elastic shock (*Al-Durrah and Bradford, 1982*). The impact of a drop on a surface is a complex phenomenon, for which the current fundamental physical knowledge does not allow to propose a model of understanding (*Range and Feuillebois, 1998; Aziz and Liatim, 2018*). Therefore, our study objective, to expose an experimental plot of 1 m^2 of a revamped agricultural soil at different intensity values to artificial rain through a rain simulator. Rain intensities used in the present study ranged from 30 mm / h to 100 mm / h; for each rain intensity, measurements of sediment concentration were performed on a regular time of 4 minutes and that for about 50 minutes. This time is almost the time for which the transport of soil particles becomes zero. After experiments, the results obtained showed us that sediment concentration is best correlated with overland flow parameters such as Reynolds and Froude numbers and friction factor (Manning roughness coefficients).

2. Material and Method

The experiments were drilled on the rainfall simulator, shown in Figure 1, consists of a sprinkler system comprising a nozzle attached to a calibrated nozzle, mounted on a movable arm and supplied with water at a constant rate by a pump spraying a floor pan of a square meters (2 meters long and 1 meter wide) atop a pyramidal tower. This in turn allows the attachment of a cover to isolate the parcel from the wind. The speed of swinging the arm controlled by a DOP drive adjusts the desired rain intensity. This same rainfall was used by *Aziz and Liatim, 2018*.

Six simulated rainfall intensities were produced by two types of spray nozzles: TEEJET SS 65 60 and H ¼ VV 8008 whose values are: 31.40 mm / h; 37.82 mm / h; 69.49 mm / h; 81.85 mm / h; 90.39 mm / h and 101.94 mm / h.

The flow rate of water-sediment mixture is removed from the compartment 10 shown in Figure 1, a test piece of 1000 ml at 4 minute intervals. Then a volume of 100 ml of this mixture is charged in a glass beaker and put in an oven at 105° C for 24 hours; it can measure sediment concentration. This process was repeated in five tests for each rain intensity.

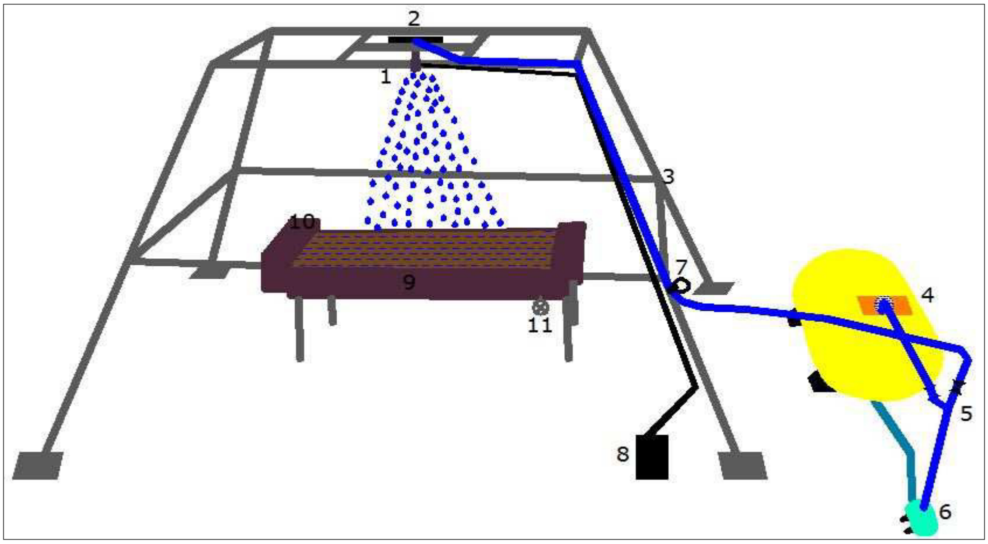

Fig. 1. Schematic representation of the rainfall simulator.
*1) Jet nozzle; 2) Movable nozzle; 3) Metal gantry; 4) Tank 600 liters; 5) Gate valve; 6) Pump; 7) Pressure gauge; 8) DOP Drive; 9) Soil Tray 2 * 0.5 m^2; 10) Waters collection compartment; 11) Slope device setting*

3. Hydraulic parameters

3.1. Reynolds number (Re)

This number, which represents the ratio of inertial forces to frictional forces, is the classification parameter for laminar, transient and turbulent flow regime. The formula usually used for shallow free surface (*Savat, 1980; Gilley et al., 1990, Abrahams et al., 1995 and Pilotti and Menduni, 1997*) is given by:

$$R'e = \frac{4 R_h V_m}{\upsilon}, \tag{1}$$

R_h– Hydraulic radius; in *m*;
V_m – Mean flow velocity; in *m/s*;
υ – Water viscosity ; in m^2/s.

For runoff, where the depth (*h*) is small compared to the runoff length, we can made R_h=h.

This expression of the Reynolds number is used by several authors (*Pan et Shangguan, 2006* ; *Hui-Ming et Yang, 2009; Peiqing et al., 2011* ; *Ali et al., 2012* ; *Guo et al., 2013b, Zhao et al., 2015 and Aziz and Liatim, 2018*). The equation 01 can be expressed as:

$$Re = \frac{h V_m}{\upsilon}. \tag{2}$$

3.2. Froude number (Fr)

The Froude number (*Fr*) is determined as the ratio of the forces of inertia to the forces of gravity, Fr <1 and Fr> 1 indicate the occurrence of a stream flow and a torrential one, respectively. On the other hand, we speak about the critical regime when Fr = 1. It describes the effect of the change in depth on the characteristics of the overland flow, it is expressed by : (*Pan et Shangguan, 2006 ; Hui-Ming et Yang, 2009 and Aziz and Liatim, 2018*)

$$F_r = \frac{V_m}{\sqrt{gh}}, \tag{3}$$

V_m – Mean flow velocity; in *m/s*;
h – Flow depth; in *m*;
g – acceleration of gravity; in m/s^2.

3.3. Manning Roughness coefficient (*n*)

The overland flow resistance factors are represented by the Darcy-Weisbach (*f*) and Manning coefficients (*n*). *Emmet (1970)* reported that roughness has the effect of increasing the depth of flow by up to 30%. *Savat (1980)* underlined the importance of soil roughness when he studied flow resistance in supercritical flow on corrugated sheets, he found that wave size can reach twice the mean depth of the flow.

The Manning Roughness coefficient (*n*) is expressed by:

$$n = \frac{h^{\frac{2}{3}}\ S^{0.5}}{V_m}. \tag{4}$$

3.4. Sediment concentration (*Cs*)

The sediment concentration is defined as the ratio of the dry mass of sediment to the flow volume. (*Mouzai,1992* and *Pan et Shangguan, 2006*). It illustrates the ability of surface runoff to erode and transport sediment.

Sediment transport for overland flow has been studied by *Julien and Simons (1985)* using dimensional analysis, the equation related the sediment concentration to a power function of flow rate and slope. A vague conclusion can nevertheless be drawn to state that the sediment concentration increases with the increase in flow rate.

4. Results and discussions

4.1. The relationship between sediment concentration and Reynolds number:

From Figure 2, the relationship between sediment concentration and Reynolds number follow an exponential law. The evolution shows that the flow regime expressed by Reynolds number is very correlated with sediment concentration with an increase equation: $Cs = 0.306e^{0.07(Re)}$ with a high coefficient of determination of 0.95. We can say that, the sediment concentration values increase with the Reynolds number values for the six rainfall intensities.

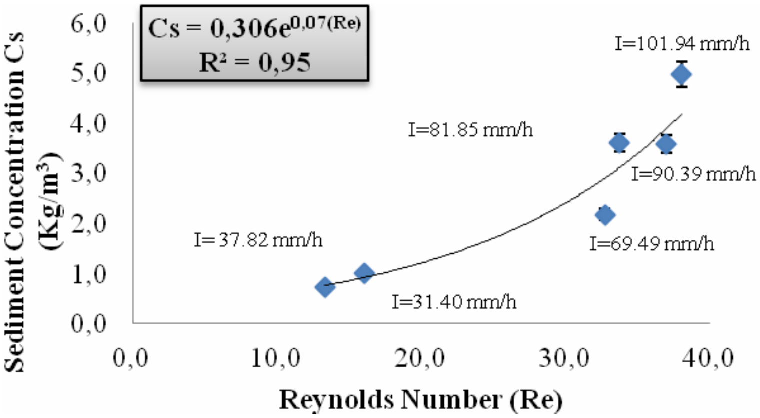

Fig. 2. Relationship between the sediment concentration and the Reynolds number

4.2. The relationship between sediment concentration and Froude number :

From figure 3, it is noted that the sediment concentration decreases with in Froude numbers.

The evolution is represented by the exponential function: $Cs = 32.31e^{-5.92(Fr)}$ with a coefficient of determination $R^2 = 0.91$. In other hand, the values of the Froude numbers calculated in this work were less than 1. The flow regime, observed for the six rainfall intensities were torrential. This turbulence can be the reason of the decrease observed in this case.

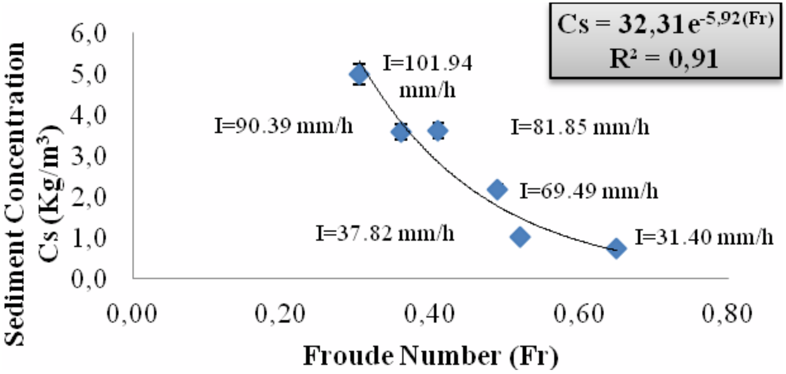

Fig. 3. Relationship between the sediment concentration and the Reynolds number

4.3. The relationship between sediment concentration and Manning Roughness coefficient (*n*):

Manning's roughness (*n*) is a parameter calculated as a function of flow velocity, flow depth and soil slope in this study. This parameter is linked at same evolution with Froude numbers with the sediment concentration, this relationship is shown in figure 04. The regression function is so an exponential function with a high coefficient of determination R^2 = 0.89. During the tests, some observations were made; for each rainfall intensity, the roughness decreases with time and at the end of the test, a smooth surface appeared, in particular on the end part of the soil pan. This observation is explained with the decrease of the sediment concentration with the Manning's roughness coefficient.

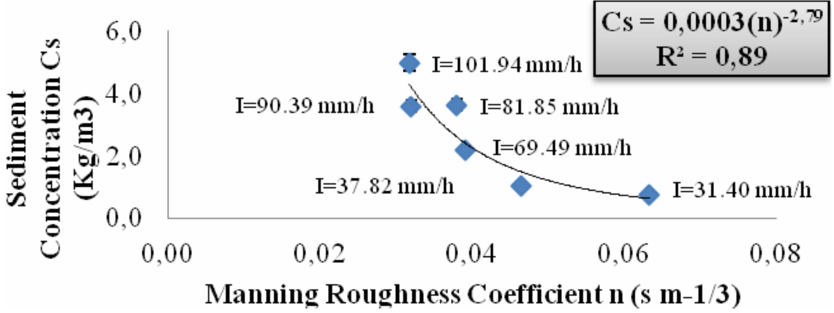

Fig. 4. Relationship between the sediment concentration and the Manning roughness coefficient (n)

5. Conclusion

In conclusion of this work we can say that the comparison between the sediment values of sediment concentrations with the flow regime and Manning's roughness coefficient, we can say that, the relationship is highly correlated and gives us the information that sediment concentration values increase with flow regime and decrease with roughness of the soil surface. Our results are consistent with the principle of *Kinnell (1990),* only the turbulence created by the impact of drops has a sufficiently large shear force to break off the soil surface particles.

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ЛАБОРАТОРНИЙ ЕКСПЕРИМЕНТ: ВПЛИВ ГІДРАВЛІЧНИХ ПАРАМЕТРІВ ПОВЕРХНЕВОГО ПОТОКУ НА КОНЦЕНТРАЦІЮ ОСАДУ

Водна ерозія відбувається завдяки поєднанню відшарування та транспортування частинок ґрунту ерозійними факторами, такими як водяний сплеск, поверхневий потік, викликаний дощем, або і тим, і іншим. Kinnell (2000); Lu та ін. (2015); Guo та ін. (2015) припускають, що на процес ерозії пологих ґрунтів сильно впливають характеристики гідравлічних поверхневих потоків (режим потоку, глибина потоку, швидкість потоку, напруга зсуву, потужність та тертя). Стік може набувати різних форм, починаючи від стоку і закінчуючи дуже тонким шаром поверхневого потоку аж до сильно дренованих концентрованих потоків, спричинених ерозією. Метою цього дослідження було спробувати виявити вплив гідравлічних параметрів на концентрацію осаду. Для дослідження цього в лабораторії проводили експериментальне дослідження з використанням імітатора опадів. Це дослідження було проведено на відновленому сільськогосподарському ґрунті, відібраному в ІТПОК Алжир (Технічний інститут промислових овочевих культур), підданому дії серії модельованих інтенсивностей опадів від 30 мм/год до 100 мм/год; потім той самий ґрунт, зазнав дії опадів і поверхневого стоку, з постійною швидкістю потоку, яка утворює шар води на поверхні ґрунту. Це дозволило нам виявити, що вплив поверхневого потоку на концентрацію осадів дуже значний.

Ключові слова: **симулятор опадів; інтенсивність опадів; стік; концентрація наносів; режим течії; піщаний ґрунт.**

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ЛАБОРАТОРНЫЙ ЭКСПЕРИМЕНТ: ВЛИЯНИЕ ГИДРАВЛИЧЕСКИХ ПАРАМЕТРОВ ПОВЕРХНОСТНОГО ПОТОКА НА КОНЦЕНТРАЦИЮ ОСАДКОВ

Водная эрозия происходит благодаря сочетанию отслоения и транспортировки частиц почвы эрозионными факторами, такими как водяной всплеск, поверхностный поток, вызванный дождем, или тем и другим. Kinnell (2000) Lu и др. (2015) Guo и др. (2015) предполагают, что на процесс эрозии пологих почв сильно влияют характеристики гидравлических поверхностных потоков (режим потока, глубина потока, скорость потока, напряжение смещения, мощность и трение). Сток может принимать различные формы: от стока до очень тонкого слоя поверхностного стока и до сильно дренированных потоков, сосредоточенных в ручьях, даже в оврагах, вызванных эрозией. Целью этого исследования было попытаться выявить влияние гидравлических параметров на концентрацию осадка. Для исследования этого в лаборатории проводили экспериментальное исследование с использованием имитатора осадков. Это исследование было проведено на восстановленном сельскохозяйственном грунте, отобранном в ИТПОК Алжир (Технический институт промышленных овощных культур), подданному действия серии моделируемых интенсивностей осадков от 30 мм/ч до 100 мм/ч; затем тот же грунт, потерпел действия осадков и поверхностного стока, с постоянной скоростью потока, которая образует слой воды на поверхности почвы. Это позволило нам выяснить, что влияние поверхностного потока на концентрацию осадков очень значительно.

Ключевые слова: **симулятор осадков; интенсивность осадков; сток; концентрация наносов; режим течения; песчаный грунт.**