Evaluating Erosion Risk on Agricultural Soils with the Modified Mini-JET Device

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INTRODUCTION

Soil erodibility is a characteristic that describes the susceptibility of a soil surface to erosion. Higher erodibility rates lead to higher shear for a particular rainfall event. For this reason, the erodibility of the soil surface is input as a parameter in a number of physical-based erosion models. In models that mathematically describe the erosion process, erodibility is usually represented by the critical shear stress of the soil surface. The critical shear stress is the value of the shear stress caused by the kinetic energy of the water flow from which the soil surface starts to erode. Critical stress can be determined by experiments, which are often expensive and time-consuming. Finding a reliable method for direct measurement of soil erodibility values would be of significant benefit for a more reliable determination of the risk of erosion of agricultural soils and subsequent design of erosion protection.

The objective of this study is to present a method for determining the erodibility of incohesive agricultural soils by measuring the critical shear stress. The method is relatively widespread around the world. However, its application to the surface of agricultural soils is quite innovative and this is the first such use of the described device.

MATERIALS & METHODS

When evaluating the erodibility of the soil, it can be assumed that the erosion rate ε_r [m.s^{-1}] is proportional to the effective shear stress τ_e [Pa]. Erosion begins when the effective shear stress τ_e [Pa] starts to be higher than the critical shear stress τ_c [Pa]:

$$\varepsilon_r = k_d(\tau_e - \tau_c)$$

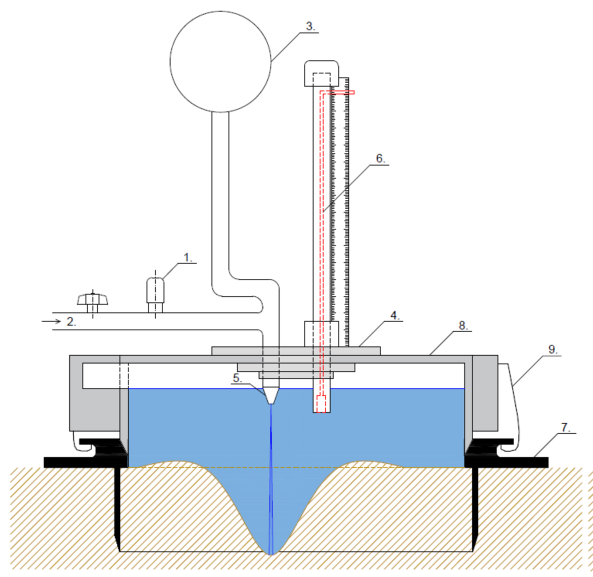
JET EROSION TEST

JET (Jet Erosion Test) is a technique used to study erosion and mechanical properties of soil. The principle is to monitor soil erosion caused by a vertically applied jet of water. A jet of water generated by constant pressure flows through the nozzle and falls onto the soil surface. The soil surface is submerged during the experiment, the nozzle is completely submerged in water, and the following erosion parameters calculations are based on the dynamics of the submerged jet. The water jet that flows out of the nozzle exerts a shear force on the soil surface, and an erosion crater is created. The JET analysis is based on the hypothesis that the maximum shear force of the water jet causes the maximum depth of the erosion crater. The measurement time and the reading of the depth of the erosion crater are performed at specified time intervals. The initial measurement time should be as short as possible in order to achieve the most accurate depth of the erosion crater. The test is considered complete when the depth of the erosion crater reaches maximum (no further deepening).

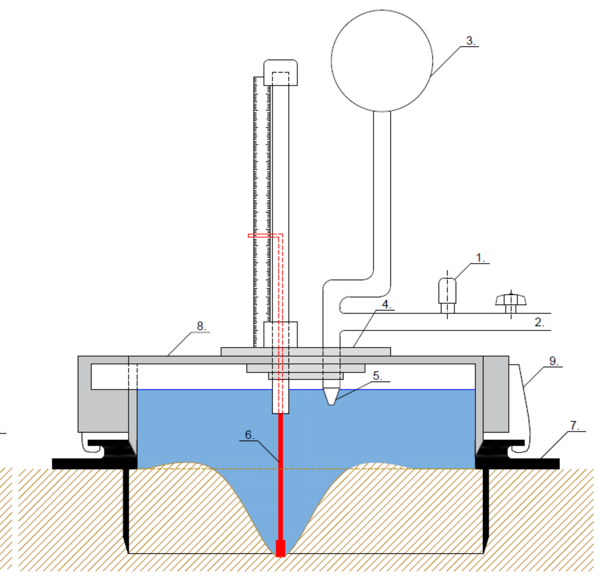
MINI-JET DEVICE

It is a smaller version of the original JET device. It has been modified for the purpose of experiments on incohesive soils. The modification is based on the modification of the diameter of the foundation ring, which has been increased so that the erosion of the incohesive soil does not extend the erosion crater close to the ring. The second significant modification is the water pressure control system, which allows the low kinetic energy of the water jet to be regulated.

Modified Mini-JET device



Working position



Reading position

EXPERIMENTAL SETUP

A total of 110 experiments were performed on different types of soil surfaces. These were mainly cultivated fallow and seedbed. For each set of experiments, soil samples were collected to determine soil physical and chemical properties such as texture, bulk density, water content, aggregate stability, and organic carbon content.

Table of measured soil characteristics

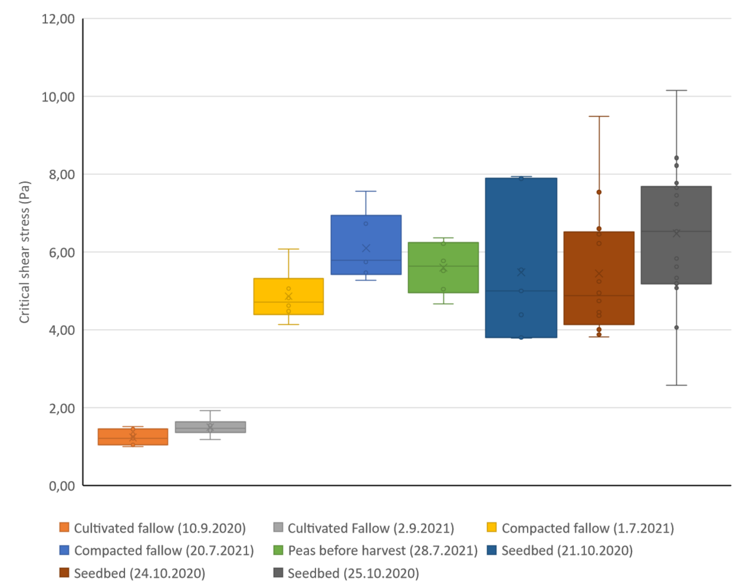
Soil surface (date)	Texture			Bulk density	Volumectric water content	Aggregate stability	Organic carbon content
	clay	silt	sand				
	[%]	[%]	[%]	[g.cm^{-3}]	[%]	[%]	[%]
cultivated fallow úhor (10.9.2020)	9,2	56,2	34,6	-	-	-	-
seedbed (21.10.2020)	8,3	54,5	37,2	1,53	29,3	55,9	1,48
seedbed (24.10.2020)	8,9	57,3	33,8	1,55	30,2	60,8	1,43
seedbed (25.10.2020)	9,9	57,0	33,1	1,48	32,3	57,8	1,68
compacted fallow (1.7.2021)	-			1,26	21,3	56,9	1,67
compacted fallow (20.7.2021)	26,5	45,4	28,1	1,43	19,2	55,8	1,27
peas before harvest (28.7.2021)	11,3	50,8	37,8	1,23	19,3	69,9	1,70
cultivated fallow (2.9.2021)	-			1,14	12,9	-	-

The objective of the experimental measurements was to monitor the formation of the erosion crater in time as accurately as possible. It is important to set the correct water pressure to ensure constant deepening of the crater. The water jet was applied to the soil surface at intervals that increased as the erosion crater was deeper. The measurement was finished when the depth of the erosion crater did not increase during the last three measurements of at least 30 s.

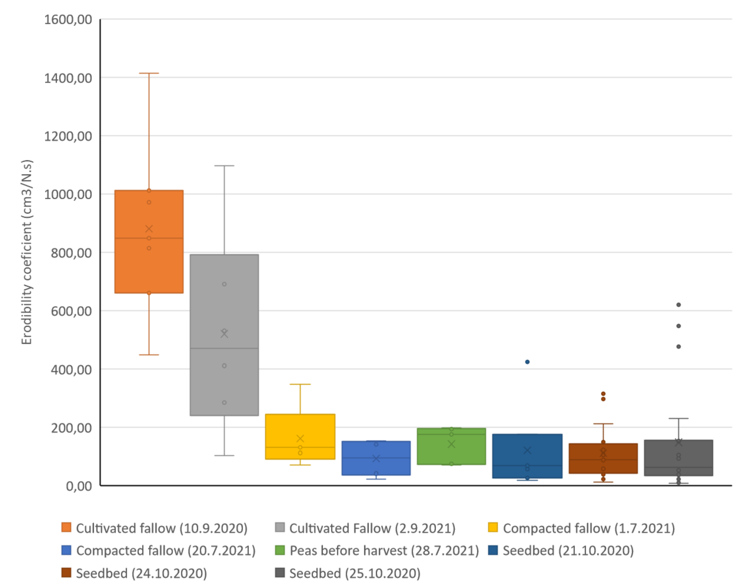
Erosion crater after the simulation

RESULTS

Using the data from the simulations, the critical shear stress τ_c and the erodibility coefficient k_d were calculated using the "Jet Erosion Test Spreadsheet Tool". The "Scour depth" method was used as a computational approach because of the similarity between the predicted and real-time course of the erosion crater deepening in the experiments.



Critical shear stress on different types of soil surfaces



Erodibility coeficient on different types of soil surfaces

CONCLUSION

- A total of 110 experimental measurements were performed on different soil surfaces.
- The overall success rate of the JET method in this case was 69 %.
- The Mini-JET device is very suitable for field measurements because it is small, light, requires relatively small amounts of water, and can be operated by one person.
- The calculated erosion parameters show that the Mini-JET can be used for measurements on incohesive soils such as agricultural soils.
- The results of erosion parameters often show a higher variability of values; therefore, it is optimal to always perform a sufficient number of replications on the soil surface.

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