Abstract

Soil forms the surface layer of the lithosphere and performs many vital functions. It contributes to the natural water cycle, regulates the climate, and provides suitable conditions for plant growth. One of the main threats driving its degradation is water erosion.

The initial stage of rainfall-induced erosion is the splash phenomenon, which involves the detachment and displacement of soil particles via raindrop impact. Research on splash erosion focuses primarily on determining the quantity of displaced material and the characteristics of ejected particles, relating the results to factors influencing the phenomenon, such as the energy of the raindrops or soil parameters. However, the drop impact also includes the deformation of the soil surface. In contrast to issues concerning the mass of eroded material, craters formed as a result of the splash phenomenon have received comparatively little attention in previous studies.

The aim of this doctoral thesis, which is based on a series of thematically related articles, was to fill a gap in the current state of knowledge by providing a detailed description of soil surface deformation caused by the impact of a single water drop in the context of splash erosion.

The range of measurement methods employed in the study enabled a multifaceted characterisation of crater morphology and an analysis of the underlying deformation process. The measurements comprised sample photography and 3D scanning, high-speed video recording of the splash phenomenon, and computed microtomography analysis. The possibilities, challenges, and development prospects for crater measurement methods were presented in a review paper (**P1**), which serves as an introduction to the experimental part of this thesis.

The materials used in the study were selected according to the specific objectives. These included glass beads, which served as a simplified soil model (**P2**), and five distinct soils with varying particle size distributions (**P3, P4**). The work carried out on the model beds enabled an analysis of the displacement of their elements depending on their initial location relative to the point of drop impact. The experiments involved the use of both dry and saturated beds. In the dry deposits, three types of displacement were identified, i.e. displacement inside the surface area wetted with a falling drop of water, ejection, and placement on the crater rim. In saturated deposits, two types of displacement were distinguished, i.e. displacement inside the deformation and ejection. The impact of the drop ejected a greater number of glass beads from the dry beds, although they travelled over shorter distances compared to those ejected from the saturated beds. The displacement of the beads depended on their initial location and the type of deformation in the area from which they originated. The presence of water within the deposits clearly influenced the morphology and extent of the deformation. Specifically, the craters formed on the dry beds were larger, and an aggregate consisting of material bound by water from the drops was formed within them (results presented in paper **P2**).

Another specific objective, addressed as part of publication **P3**, was to determine the influence of the soil's initial moisture content, particle size distribution, and drop energy on the morphology and size of formed craters. Measurements were taken using a 3D surface scanner to determine crater depth, equivalent diameter, circularity, and volume. A factor exerting the greatest influence on deformation was the moisture content, where higher moisture levels resulted in larger craters. The particle size distribution influenced crater circularity, which was greater for materials with a higher silt fraction content. An increase in drop energy led to an increase in the mean values of the measured parameters, although these changes were not statistically significant in every case.

The third research paper (**P4**) examined the effect of temperature on crater size. The experiments involved three soils, two initial moisture contents, and three temperature variants. Measurements were taken using a surface scanner. The crater characteristics included depth, equivalent diameter, volume, and the dimensionless parameter α (the depth-to-diameter ratio). The effect of temperature resulted mainly from its interaction with other factors. In silty loam, the increasing temperatures resulted in wider but shallower craters. In loamy sand, the temperature variations led to statistically significant differences in the diameter and volume of craters formed at different moisture contents. However, it should be noted that the effect of temperature was significantly smaller than that of moisture content or particle size distribution, and it was not observed in the sandy loam.

The doctoral thesis contributes to the development of knowledge regarding the physical description of the splash phenomenon, focusing in particular on the deformation of the soil surface caused by drop impact. The results are important for understanding the mechanisms by which bacteria, fungi, and contaminants are transported along with displaced soil particles. Additionally, the potential application of the crater analysis results includes their incorporation into erosion models to better predict the scale of current and future soil loss.

Keywords: soil erosion, splash phenomenon, surface deformation, crater, 3D scanning