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The new volumetric approach for field measurements of rill erosion

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Abstract

Erosion on the agricultural soils in the Czech Republic threats seriously their production and nonproduction functions. Erosion have devastating effect on fertile topsoil of the agricultural soils, reduces the thickness of the soil profile and nutrients and humus content, deteriorate physical, chemical and biological properties of soil. At the Brno University of Technology in Czech Republic was designed and realized equipment "the soil erosion bridge", which allows the soil surface profile measurement and quantifies the volume of erosion rills, which can occur after heavy rainfall. The main objective was to develop a method for volumetric quantification of erosion rills during heavy rainfall season. Using new equipment the soil surface profile was measured directly in the field during 4 years (2007–2010). New equipment consists of three parts. The first equipment is a square frame with an inside dimension of 4 m^2. The second equipment is removable profile, which serves for movement of the soil erosion bridge. The third equipment is the soil erosion bridge. The soil erosion bridge serves to volumetric quantification of rill erosion. The more effective way of data processing was developed. It was developed a software, by which it is possible the automatically transfer the rill surface profile to digital form.
In the South Moravian Region in the Czech Republic was selected case study area with typical very steep sloped relief with the loess soil. The measurement was carried out on the research plots with a slope of more than 10%. More than 1300 cross sections of the soil surface profile were measured using the new type of soil erosion bridge. From these profiles it was possible to calculate the volume of the eroded soil from the research plots. The results were always in excess of 100 t.ha^{-1}.rok^{-1}. This is a value many times higher than the tolerated limit of soil loss in Czech Republic. Thanks to this new equipment, it is possible to quantify the soil loss from the plot threatened of water erosion. The advantage of this equipment is its using during the vegetable season when the soil surface is overgrown with vegetation and crops are higher growth.

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Introduction

In the Czech Republic soil erosion is a significant degradation process, which threats more than half area of the arable land nowadays. The extent of the actual water erosion is 1780000 ha in the Czech Republic that is 42% of agricultural land. The significantly damaged plots occupy 450,000 hectares (10.7%) of the agricultural land (Vopravil et al., 2010a, 2010b). Wind erosion threats 10.4% of arable land, mainly in southern Moravia (Janeček et al., 2011).

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Water erosion has a negative impact directly on-site by reducing the production and retention capacity of the soil. From the poit of view of water management water erosion causes the sediment transport from the catchment and their sedimentation in the hydrographic network and in the water reservoirs. Up to 5% of reservoirs volumes are clogged every year. It is estimated that about 200 million m^3 of sediment in reservoirs in the Czech Republic is accumulated (Zapl et al., 2009).

The goal of paper is measuring the soil loss from the hillside on a concrete plot, where it is grown the wide-row crop (maize). The process of measurement and evaluation of the volume eroded soil caused by water erosion is called volumetric quantification of soil loss by water erosion. At the Institute of Landscape Water Management, Faculty of Civil Engineering, Brno University of Technology in the Czech Republic was designed and realized e equipment "the soil erosion bridge", which allows the soil surface profile measurement. Thanks to measurement the soil surface profile, it is possible to quantify the volume of erosion rills, which can occur on sloping hillside after heavy rainfall. The first idea leading to the measuring of changes of soil surface profile by equipment look like wooden bridge had Ranger et al. (1978). They calculated soil loss on the plots, which were created by cutting trees. A similar type of equipment for measurement the volume of ephemeral gullies and its principle was described by De Santisteban et al. (2006).

Material and Methods

The Theory of Surface Runoff and Erosion Process

The process of water erosion occurs and runs in the context of water runoff on the soil surface. Runoff on the hillside runs the first like surface runoff, and then the concentration of runoff occurs due to unevenness of the soil surface and surface runoff changes into concentrated runoff (Holý et al., 1982). Principle of water erosion resides in leaching soil particles by water and their accumulation in the form of sediment, which are further transported and subsequently they are deposited in the area of accumulation, in the hydrographic network and in the reservoirs.

Water erosion on plots of catchment we can divide on sheet erosion (inter-rill), rill erosion, ephemeral gullies erosion in the waterway with concentrated surface runoff and gully erosion. The paper regards the problem with rill and inter-rill erosion. The inter-rill erosion is caused by the kinetic energy of the rain drops and the surface runoff when leaching particles by rainfall are transported to the area of erosion rills (Toy et al., 2002). The rill erosion occurs by surface runoff with transport of particles from inter-rill area and subsequently by concentrated surface runoff of small depth in own erosion rills (Toy et al., 2002).

Area Description

The research areas were selected in cadastral Šardice, where is very typical steep sloped relief with the loess soil. These are situated in a catchment of Šardický stream, which is located in the Czech Republic in The South Moravian Region (Figure 1). The catchment lies in a warm area. The case study areas were situated on chernozem and the measurement run in the years 2010, 2009, 2008 and 2007 (Figure 1).

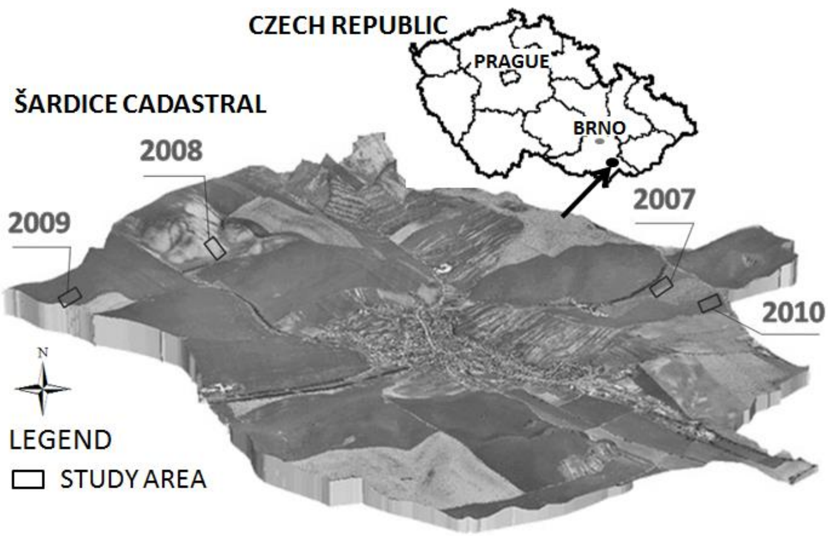

Figure 1. Situation map of the Šardice cadastral with detailed locations of the case study areas in the year 2007–2010

Methods

The measurement by the erosion bridge were carried out directly in the field on the concrete plots The case study area were located on plots with a slope over 10%, and there was grown wide-row crop (maize) cross down the hillside. Thanks to the erosion bridge was measured about 1300 soil surface profile (erosion rills profiles) in the field. The volume of eroded soil from erosion rills were calculated by the soil surface profile. Measurement of soil loss in the field runs during the four years 2007–2010 (Figure 1). In the every case study area were situated two transects labelled T1 and T2 (Fig. 2). Each transect consist of five measured square area, labelled I, II, III, IV, V (Figure 2). Square areas were situated in upper part of hillside (the nearest the labelling T1 and T2 on the figure 2), in the middle part of hillside and in lower part of hillside.

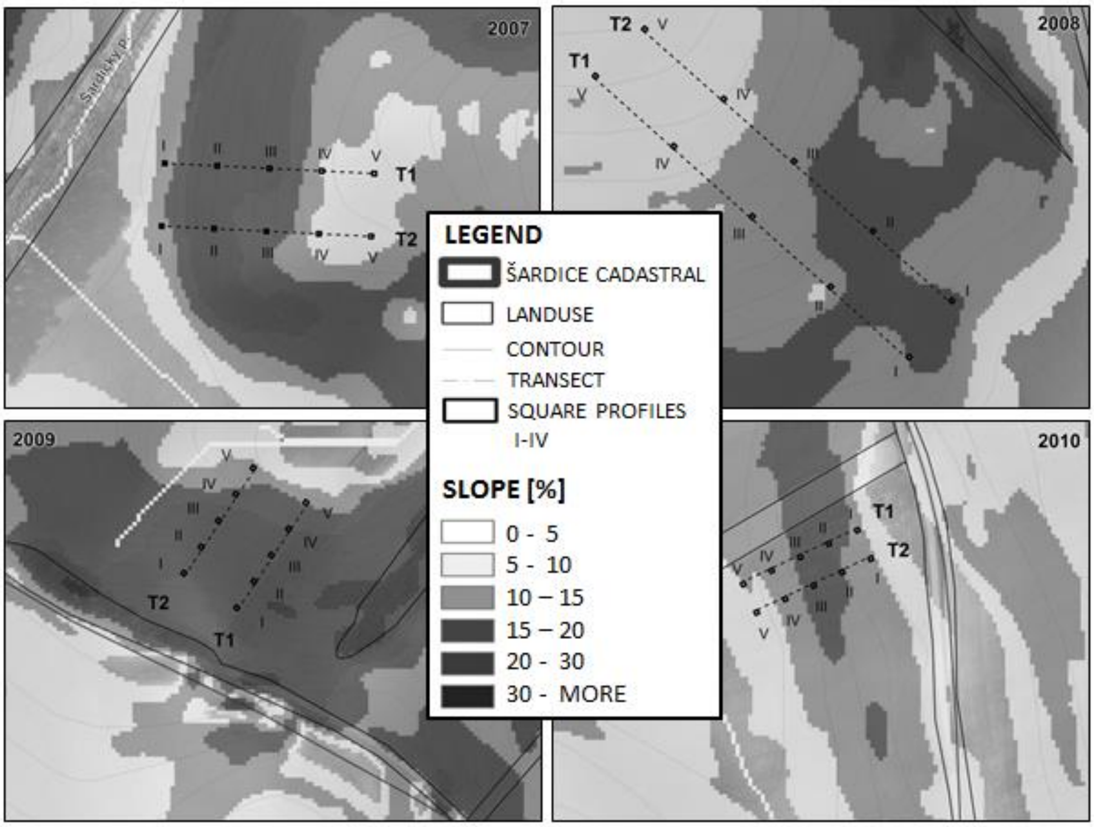

Figure 2. Location of transects T1 and T2, square area I–V during year 2007–2010 and slope of surface in %

The soil erosion bridge consists of the 3 equipment (Figure 3a). The first equipment is a square frame with an inside dimension of 2 times 2 m, which is situated on the four point. The second equipment is removable profile, which serves for movement of the soil erosion bridge to measuring length 2 m of soil surface profile. The third equipment is the soil erosion bridge. The soil erosion bridge serves to volumetric quantification of rill erosion obtains from the soil surface profile (Figure 3b).

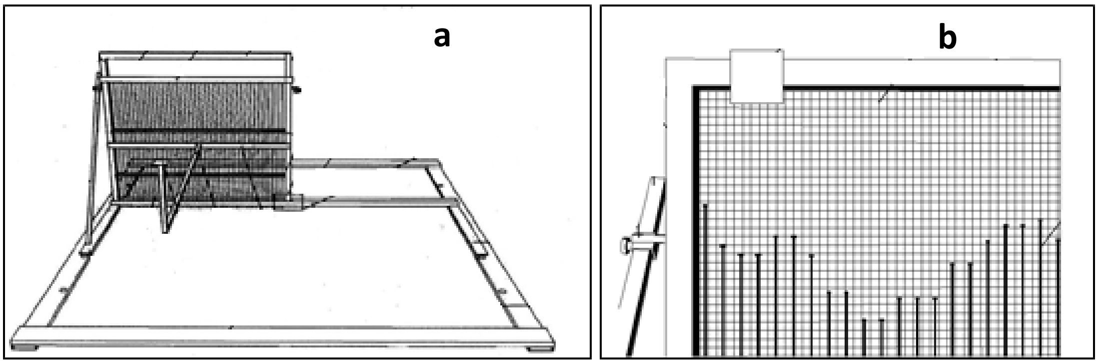

Figure 3. The equipment the soil erosion bridge with drop down pins (a) and detail of the soil erosion bridge with drop down pins in the field

Results and Discussion

Field measurement was carried out during 2007–2010. It was made measuring of soil surface profiles on transects T1 and T2 leading cross down the hillside (Figure 2). Each transects included 5 square area of area 4 m^2. Square areas were situated on these landscape positions on hillside. Square area I was situated in the upper part of the slope, square areas II-IV were situated in the middle part of the slope and the square area V was situated in the lower part of the slope (it isn´t the area of sedimentation, but the area of decreasing slope). Within each square area 5 soil surface profiles with a length of 2 m were measured (Figure 4). For each location of the soil erosion bridge in individual profiles photo of pins position was taken. Photo was subsequently evaluated and graph of soil surface profile was generated (Figure 4).

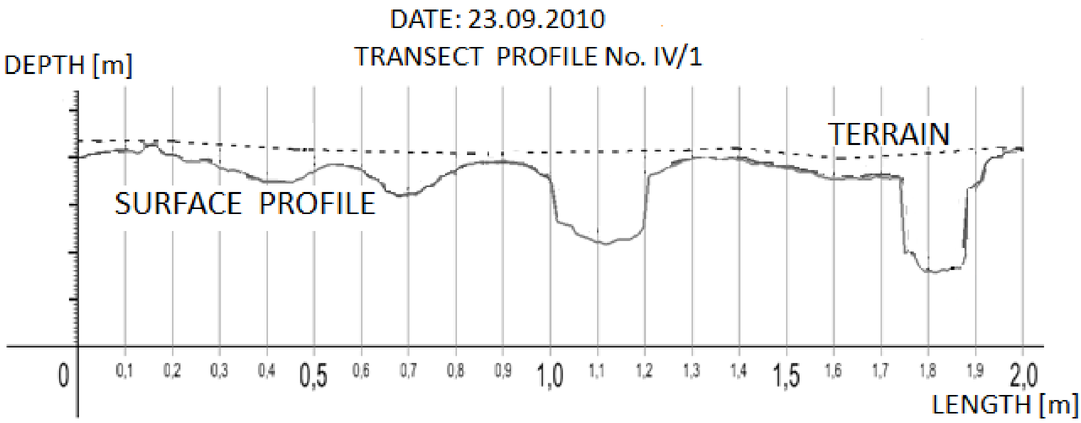

Figure 4. Graph of soil surface profile IV/1

Totally 1300 the soil surface profiles were measured and evaluated. The value of soil loss in m^3 is the result. Furthermore, the soil loss from m^3 was recalculated to average soil loss in t ha^{-1} (Table 1). The average bulk density obtained from the evaluation of the sampling from the transect area to convert of soil loss units was used.

Table 1. Measured soil loss and average soil loss in m^3 from transects T1, T2 and average soil loss in $t.ha^{-1}$ from hillside area during years 2007–2010

Year	No. Transect	Soil loss from transect T1 and T2	Average soil loss from transects	Average soil loss from hillside area
		[m^3]	[m^3]	[$t.ha^{-1}$]
2010	T1	0.121	0.109	444.420
	T2	0.096		
2009	T1	0.050	0.063	245.450
	T2	0.076		
2008	T1	0.133	0.125	496.030
	T2	0.118		
2007	T1	0.064	0.060	214.830
	T2	0.055		

In Czech Republic the tolerated limit of soil loss is 4 $t.ha^{-1}.rok^{-1}$. Table 1 show that tolerated limit of soil loss is many times exceeded. Measured soil loss using the soil erosion bridge reaches values almost 500 $t.ha^{-1}$ (Table 1). Measured transects were selected randomly in hillside. It can show the average occurrence rill and inter-rill erosion.

Higher values of soil loss state Blaney et al. (1983), who measured soil loss almost 600 $t.ha^{-1}$. Similarly, high levels of soil loss state Štreit et al. (2004), who measured soil loss 133.777 $m^3.ha^{-1}$, which is about 214 t. ha^{-1}. In the article the results confirm the high erodibility of loess soils that are in the research area.

The measurement also allows the identification and evaluation of rill and inter-rill areas within the square areas (Figure 5). From assessment of the square areas situated in different landscape positions on the hillside follows, that occurrence of rill and inter-rill areas is relatively the same. On the hillside occur approximately 46% rill areas and 54% of the inter-rill areas. Inter-rill areas predominate in the upper and lower part of the hillside. In the middle part of the hillside it can be relatively the same occurrence of rill and inter-rill areas.

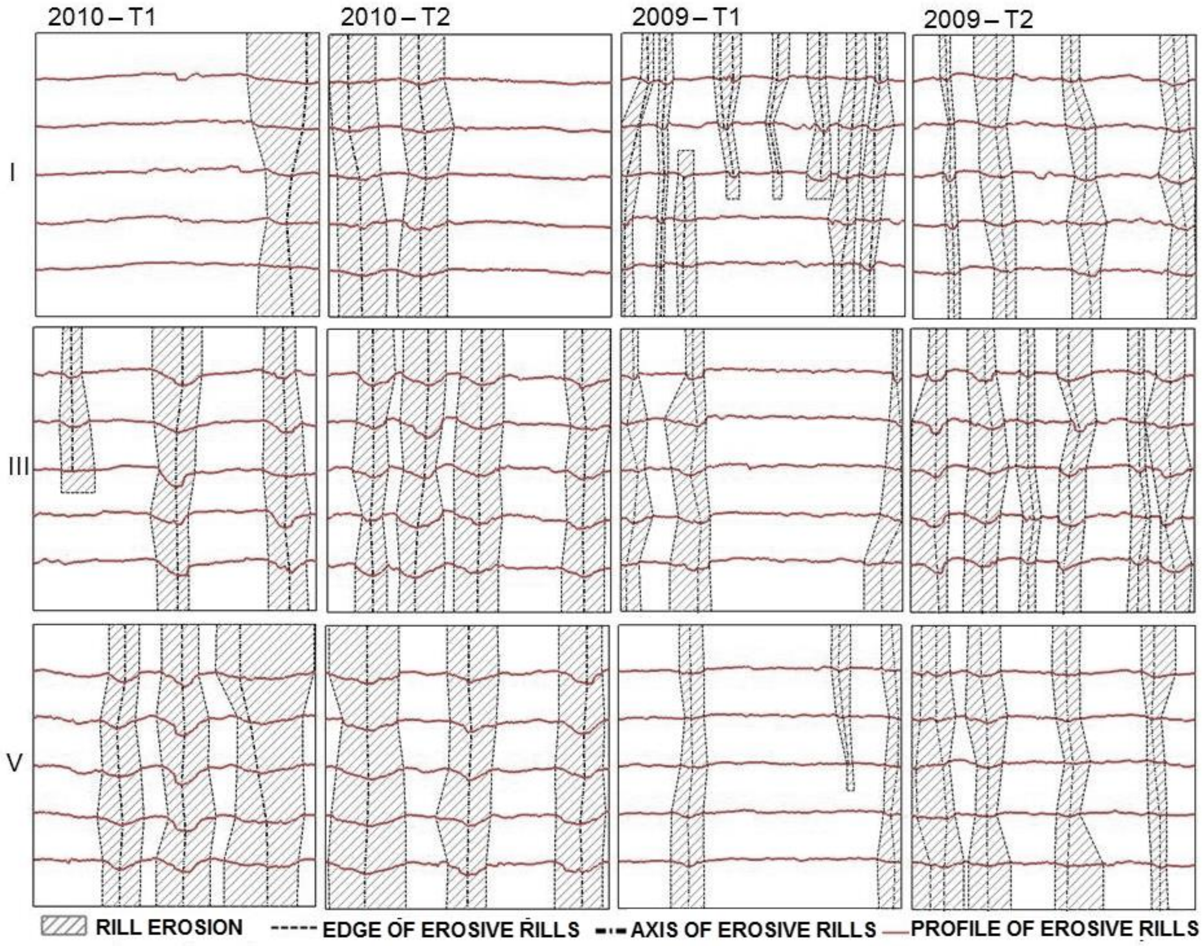

Figure 5. Rill and inter-rill area from square area situated in upper (I), middle (III) and lower (V) part of hillside from transects T1, T2 in 2009 and 2010

Conclusion

Thanks to this method of direct field measurement, it is possible to determine the value of soil loss after heavy rainfall. It can evaluate both the length and the width and depth of erosion rills, and thus quantify the volume of soil loss on the concrete plot. Based on the calculated values of soil loss, which are many times higher than the tolerated limit of soil loss in Czech Republic, it is possible to calculate the volume of eroded soil and it is possible to determine the volume of transported sediment into water streams and reservoirs. It is necessary to notify that on the slopes above 10% is not suitable to grow wide-row crops (maize). The paper shows, that there is a large soil loss on these slopes of hillside. The obtained final values and the used method will be the motivation for further scientific research on the field of soil erosion and for finding out another result of soil loss by volumetric quantification of soil loss by water erosion directly in the field.

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