1 Introduction

Water erosion is one of the most widespread forms of soil degradation. Reducing the erosion is one of many challenges worldwide and Europe (Lieve Van-Camp et al., 2004) or (Boardman et al., 2006). In particular, sediment transport from arable land into surface waters (streams, rivers, reservoirs) is one of the major problems of water management. Measuring and consequence modeling of the surface process are a necessary tool for the protection of the soil.

Two major surface processes influenced erosion (i) sheet flow with sheet erosion and (ii) rill processes. Sheet flow energy is less than kinetic energy of the raindrops in sheet erosion (Bryan – B., 2000). Rate of erosion are influenced by vegetation cover that reduced impact of the rain energy. In the other hand rill erosion is generated by a concentrated flow and this process are more closely to stream processes Gimnez – Govers (2008); Govers et al. (2007).

It is difficult to describe annual rate of soil erosion in the watershed over spatial and time scales. Long-term measurements and sufficient data base needed in order to investigate the response of erosion rates. Only abnormally high rainfall or an extreme event can produce main part of soil damage. Spatial scale of measuring are crutial as well. Many studies that focused to scaling (temporal and spatial) are published. For example Chaplot – Poesen (2012) deal with comparison of runoff and soil loss across the scales. In other studies Cerdan et al. (2002); Auerswald et al. (2009); Bauer et al. (2014) the effect of the scales to erosion is evident.

In a few available studies, the sediment yield from a hill slope or a catchment is likely to be less than the total sediment mobilised within it and estimated from plots Walling (1983). Due to sedimentation, only a relatively small proportion of the detached and transported soil material reaches the catchment outlet Beven et al. (2005); Verstraeten – Poesen (2001). Additional measurements and observations in different spatial scales in one place is still required.
Long therm field measuring have uncertainty in feather. Rainfall simulation is one of the way that make possible to measured in controlled condition. Rainfall simulation experiments are widely used as a standard method to study various flow and transport processes induced by rainfall. They have been used on different slopes, scales, soils and vegetation cover Otero et al. (2011); Davidova et al. (2016), etc. Surface runoff rate and sediment yield are standard variables observed in experiments oriented on soil erosion research with use of rainfall simulators. The review of simulators used across Europe provides (Iserloh, 2013). Due to the nature of the device the small simulators with watered area around 1 m2 are more frequent. Larger simulators can be found as well, as described for example in Sangüesa et al. (2010), Strauss et al. (2000) Marques et al. (2007), (Kavka et al., 2015).
Long-therm measuring and rainfall simulations are essential for a consequent mathematical modeling. Computer based physical models can be used for erosion pre-

diction over a wide range of conditions. To ensure model validity, simulation results must be compared with field measurements. Models can only work when they are applied to conditions. Due A desirable model should satisfy the requirements of universal acceptability; reliability; robustness in nature; ease in use with a minimum of data; and ability to take account of changes in land use, climate and conservation practices.

Many models was created and are constantly improved over the last twenty years. The specific conditions of formation, calibration and use of each models can't lead to universally valid model. General review article about models are in Pandey et al. (2016). These fifty selected models essentially reflects the wide range of models including classification according they characterization.

Mathematical modeling is very important for describing erosion processes and for soil conservation. Generally, there are two types of models of soil erosion and surface runoff: (i) empirical models often USLE (Wischmeier – Smith, 1978) or RUSLE (Renard et al., 1991) based and (ii) physically based models. Parameterisation of the emperical models based on measurements often at standardised field plots in accordance with the estimation of USLE factors or on datasets from rainfall simulators (Davidova et al., 2016). Physically based models have for their goal to create a mathematical description of process. Hydrolgical and hydraulical equations for watter balance and moving are base of approach. The models principally describe the processes of precipitation, infiltration, evapotranspiration, surface runoff, influence of vegetation. Loading, trasportation and sedimentation processes are in interconnection with surface water processes. Interconnections of precipitation, runoff, infiltration and soil erosion have become very important topics. A wide group of the models can be represented by WEPP (Laflen et al., 1997), KINEROS (Woolhiser et al., 1989), EROSION 2D/3D (Schindewolf – Schmidt, 2012) and model SMODERP that is object of this this article.

2 Material and Methods

The model has been developed since the end of the 1980´s at the Department of Irrigation, Drainage and Landscape Engineering, Faculty of Civil Engineering, Czech Technical University in Prague. The first version of 1D model, designed in the FORTRAN programming language, was developed in 1989 (Holy et al., 1988). Model based on *kinematics approach for sheet flow with special form* MKWA.

$$q = a.h^b \tag{1}$$

*where **a** and **b** are calibrated parameters and **h** watter lewel*

Parameter a based on slope and soil type, parameter b based only on soil type. The parameters developed only for tree soil types groups according contemporary soil system classification. Parameters are derived based on measurements on the hydraulic trough, more about methodology of the measurement are i the section ??

Tabulka 1: Original and corrected parameters for MKWA based on hydraulic trough

Půdní druh		b	X	Y
Písčitá	původní	1.8415	24.11	0.4869
	zpřesněné	1.8614	25.47	0.4913
Hlinitá	původní	1.748	28.64	0.541
	zpřesněné	1.7362	29.46	0.5519
Jílovitá	původní	1.5847	45.62	0.5614
	zpřesněné	1.5847	47.52	0.5614
Plexisklo	původní	1.6038	51.11	0.5471
	zpřesněné	1.5928	49.81	0.5431

Description of programming this version are in (Holy et al., 1988). Two basically independent sub-models: (i) sub-model 1 used for the calculation of admissible slope length and designing of soil conservation measures, (ii) sub-model 2 designed for the calculation of runoff characteristics in order to implement soil conservation measures. Other versions of the model, launched particularly between 1996 and 2001, further developed operating systems, but internal processes wasn't modified. However, these versions did not considerably interfere with parameters and relations inside the model.

A new version of the 1D model with name SMODERP 10.01 was carried out in 2011 (Kavka, 2011). This version of the model involved changes in the model especially the parameters of MKWA was changed. The changing are:

- Runoff parameters in the MKVA was re-calibrated,
  - small correction of the original parameters *4*,
  - based on laboratory rainfall simulation (*107 simulations1*) runoff parameters was estimated for all soil types in accordance with the Czech system of soil classification (CTCSS) (Němeček et al., 2011) occurred.
- Modification was introduced by replacement of the current generation in slopes. Previously version of the model functioned in particular sections of various lengths which had been initially defined as parts of the slope between two contour lines with identical vegetation and soil types. New approach can divides the aforesaid sections into individual elements of the same length and forms thus.
- The time step was fixed at a value of 0.2 min. Fixed time step caused in earlier versions of the model oscillations and instability numericnou calculation. The

model implentovny in accordance with the division of spatial elemnty also three fixed time steps so as to ensure stability calculation.

- old version of the model worked with unevenly long stretches. Each segment was defined as part of the slope between two contour lines with the same type of vegetation and the same soil type (based on maps in 80.). It has been shown that the unevenly size skews result. Sections are subdivided into individual equal elements automatically in this version. This is a transition from a partially split (semi-distributed) model on the model divided (distributed).

Tabulka 2: Recalibrated parameters (Kavka, 2011)

Runoff parameters			
soil type	b	X	Y
sand	1.8165	23.3	0.4981
loamy sand	1.7925	26.03	0.5202
sandy loam	1.7685	28.75	0.5308
loam	1.7385	32.16	0.5394
clay loam	1.7025	36.26	0.5467
clayey	1.6665	40.35	0.5521
clay	1.6185	45.8	0.5578

Spatial model with the support of GIS applications began to be developed in 2012 and its development continues till now. Nothing less the first problem which proved to be crucial are nonstandard units that have been used for the calibration parameters b, X, Y equation MKWA. These non-linear and statistically derived parameters could not be easily transform. It was necessary to convert all input values to SI units and the calibration procedure are have repeated. The new calibration was performed on the extended (ten years) set of the lab rain simulator. For verification was first used data from field simulations using a rain simulator (Kavka et al., 2015). The parameters corresponding with SI units are in table 3

The 2D model which is developed in last year is prepared as an extension to the widespread GIS software ArcGIS. The actual script to calculate the 2D model was elaborated in Python and used in ArcGIS standard tools. Python is a remarkably powerful dynamic open-source programming language that can be widely used and supported. Python was first introduced to the ArcGIS version 9.0. Since then, Python has been considered as a scripting language for the analysis of spatial data. In the future, the most memory and time consuming parts of the script will be overwritten in C++ with the purpose to shorten the runtime script. Moreover, besides mathematical calculation of surface runoff, the 2D model also includes a submodel implemented for runoff calculation in the rills.

Tabulka 3: Recalibrated parameters to SI(Neumann – Kavka, 2015)

Runoff parameters			
soil type	b	X	Y
sand	1.8165	8.8133	0.3661
loamy sand	1.7925	9.2043	0.4622
sandy loam	1.7685	9.5953	0.5150
loamy	1.7385	10.0841	0.5613
clay loam	1.7025	10.6706	0.6028
clayey	1.6665	11.2571	0.6358
clay	1.6185	12.0391	0.6717

Původní ovození odtokových parametrů MKWA byly stanoveny na základě vyhodnocení měření průtoků a výšek hladin na sklopném žlabu. Měření byla prováděna v Brně v roce 1984 Holy (1984). Systém spočíval v měření výšky hladiny proudící vody ve žlabu s různými druhy půd, které byly naneseny v tenké vrstvě na jeho dno a to při různých průtocích a sklonech. Díky tenké vrstvě půdy bylo možné uvažovat povrch bez vlivu infiltrace. Takto bylo provedeno měření na hladkém povrchu (plexisklo) a na třech typech půd (lehké, střední a těžké). Cílem měření bylo stanovit parametry vztahu mezi průtokem a výškou hladiny pro plošný povrchový odtok. Tyto parametry byly určeny na čtyřech površích. Povrchem byla:

- lehká půda (částice jemného písku do velikosti 0,01 mm),
- středně těžká půda (vzorek odebrán ve Velkých Žernosekách),
- těžká půda (jílovité částice - spraš),
- plexisklo (referenční povrch bez vzorku půdy).

Středně těžká půda, která byla odebrána z experimentálních ploch ve Velkých Žernosekách, obsahuje průměrně 22 % zrn první kategorie, lze ji zatřídit jako hlinitopísčitou půdu. Půdy těžká a lehká byly vytvořeny uměle a obsahovaly pouze zrna dané kategorie. Průměrně lze těžké půdy zařadit podle Novákovy klasifikace jako jílovité půdy s průměrným obsahem jílnatých částic 75 %. Lehkou půdu pak lze podle Novákovy klasifikace zatřídit jako písčitou s uvažovaným množstvím zrn první kategorie 10 Prvním krokem při posuzování funkčnosti modelu bylo nejprve zopakováno a ověřeno vyhod-nocení výsledků měření na sklopném hydraulickém žlabu Holy (1984). Vyhodnocení jednotlivých měření uvádí tabulka (viz Tabulka 10). Hlavním důvodem bylo ověřování ověření použitých jednotek. Původní statistické vyhodnocení bylo provedeno v jiných jednotkách, než ve byl napsán zdrojový kód.

Ze srovnání vyplývá, že rozdíly hodnot jsou relativně malé. Tyto rozdíly jsou pravděpodobně způsobeny výpočtovými možnostmi nebo nutným zaokrouhlením.

Tabulka 4: Original and corrected parameters for MKWA based on hydraulic trough

Půdní druh		b	X	Y
Písčitá	původní	1.8415	24.11	0.4869
	zpřesněné	1.8614	25.47	0.4913
Hlinitá	původní	1.748	28.64	0.541
	zpřesněné	1.7362	29.46	0.5519
Jílovitá	původní	1.5847	45.62	0.5614
	zpřesněné	1.5847	47.52	0.5614
Plexisklo	původní	1.6038	51.11	0.5471
	zpřesněné	1.5928	49.81	0.5431

Pro další vývoj byly použity zpřesněné hodnoty. Výsledky na hladkém povrchu je možné považovat za limitní a pro běžné půdy nepřekročitelné. Při porovnání mezi hladkým povrchem a jílem je patrné, že rozdíl není nijak významný, což je dáno velikostí jílových zrn.

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