DEVELOPING RELATIONS BETWEEN SOIL ERODIBILTY FACTORS IN TWO DIFFERENT SOIL EROSION PREDICTION MODELS (USLE/RUSLE AND WEPP) AND FLUIDIZED BED TECHNIQUE FOR MECHANICAL SOIL COHESION

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Abstract

Soil erosion models are valuable analysis tools that scientists and engineers use to examine observed data sets and predict the effects of possible future soil loss. In the area of water erosion, a variety of modeling technologies are available, ranging from solely qualitative models, to merely quantitative equations. The main purposes of this study performed in ***USDA-National Soil Erosion Research Laboratory (NSERL)*** can be summarized as developing soil erodibility equations in the defined models by obtaining new data set under rainfall experiments and intending to fill a gap between the USLE/RUSLE-based erosion prediction technology and the process-based ***WEPP*** model which is partitioned depending upon the water erosion process (splash (detachment), interrill and rill erosion processes). In this context, soil erodibility potentials of two different soil samples were collected from the State of Washington and qualified under simulation conditions and the relationships between process-based erodibility parameters such as interrill and rill erodibility and critical shear stress and the empirically based ***USLE/RUSLE-K*** term were investigated. ***Rainfall simulations*** were performed in NSERL lab under a sequence of rainfall intensities: 50 mm h^{-1} for one hour, 25 mm h^{-1} for 20 minutes, 75 mm h^{-1} for 10 minutes, and 100 mm h^{-1} for 10 minutes to obtain erosion data sets with 4 different intensities. This data was used to derive **interrill erodibility (K_i)**. A mini-flume with a gradually increasing flow rate conditions was used in order to derive **rill erodibility (K_r)** and **critical shear stress (τ_c)**. And, **Fludization Bed Technique**, proposed new approach for measuring mechanical soil cohesion in laboratory conditions was performed to obtain newly relationships between models and technique.

Key words: soil erodibility, interill erodibility, rill erodibility, critical shear stress, fludized bed technique, USLE/RUSLE, WEPP

MATERIAL and METHODS

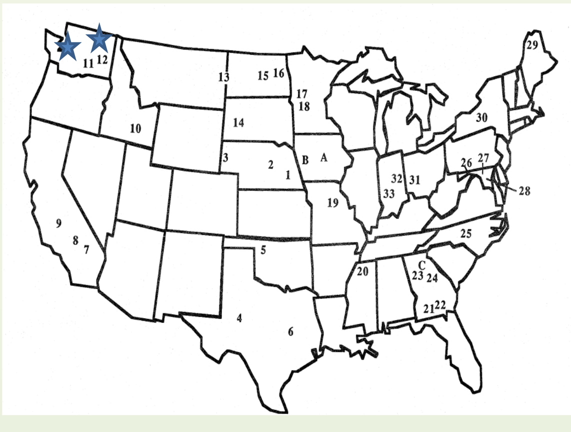


Fig. 1. Location of the WEPP cropland erosion sites

Two soils were used in this experiment –**Nansene (silt loam) (11) and Palouse (silt loam) (12) sampled from ARS Research Station in Pullman, WA on 28-29, September, 2013**.

Table 1. Some chemical and physical properties of the research soils

Soil Series	Very coarse sand % (2-1 mm)	Coarse sand % (1-0.5 mm)	Medium sand % (0.5-0.25 mm)	Fine sand % (0.25 -0.10 mm)	Very fine sand % (0.10-0.05 mm)	Silt % (0.05-0.002)	Clay % (<0.002 mm)	Texture class	Soil pH	Organic Carbon %	CEC meq/100 gr
Palouse	0	2.3	4.6	6.4	12.3	64.8	9.7	Silt loam	4.7	**2.27**	16
Nansene	0	0.5	2.5	4.9	15.6	67.1	9.5	Silt loam	5	**1.12**	16.6

Results and Discussion

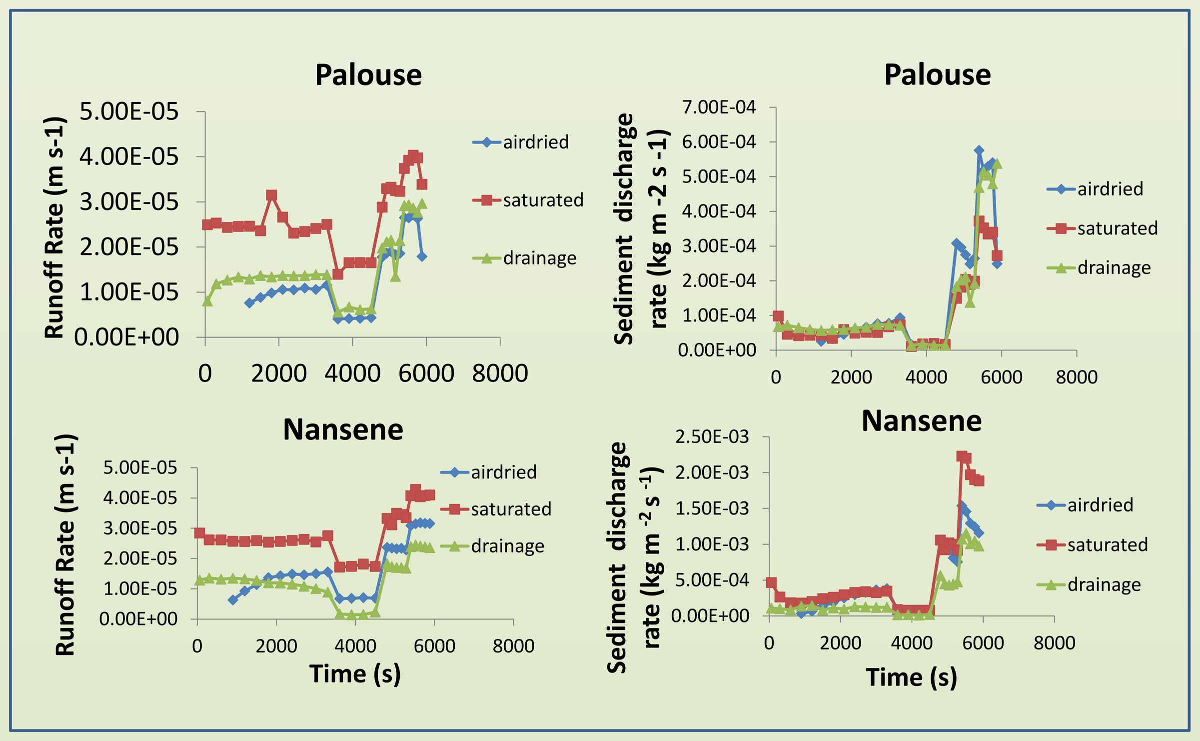


Figure 2. Interrill experiment results

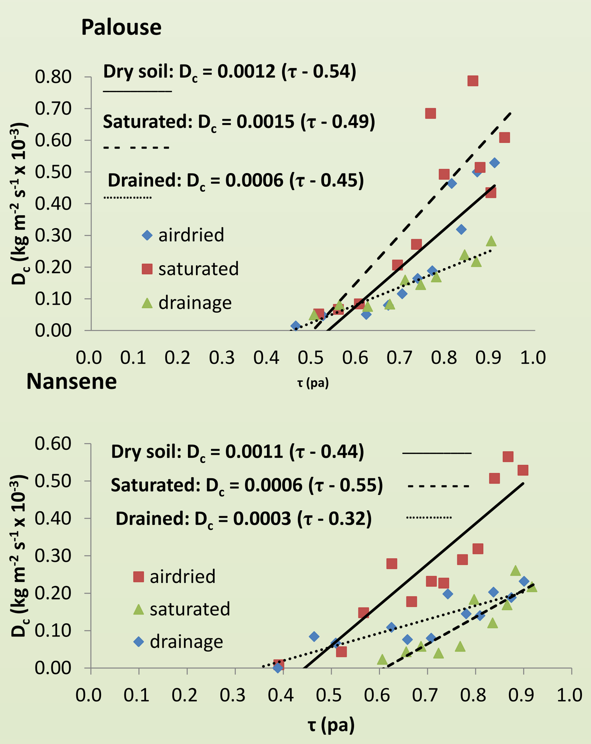


Figure 3. Rill experiment results

Table 2. Measured interrill erodibility values (kg s m^{-4})

	Palouse (Silt loam)	Nansene (Silt loam)
K_i-dry	1.31E+06	3.34E+06
K_i-saturated	4.92E+05	2.53E+06
K_i-drainage	9.91E+05	2.69E+06

Table 3. Measured rill erodibility (kg s m^{-4}) and critical shear stress (pa)

	Palouse (Silt loam)	Nansene (Silt loam)
K_r-dry	0.0012	0.0011
K_r-saturated	0.0015	0.0006
K_r-drainage	0.0006	0.0003
τ_c-dry	0.54	0.44
τ_c-saturated	0.49	0.55
τ_c-drainage	0.45	0.32

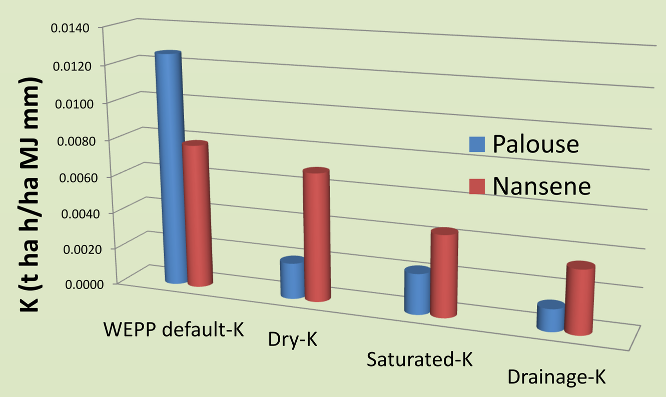


Figure 4. A comparison of the back-calculated USLE K values

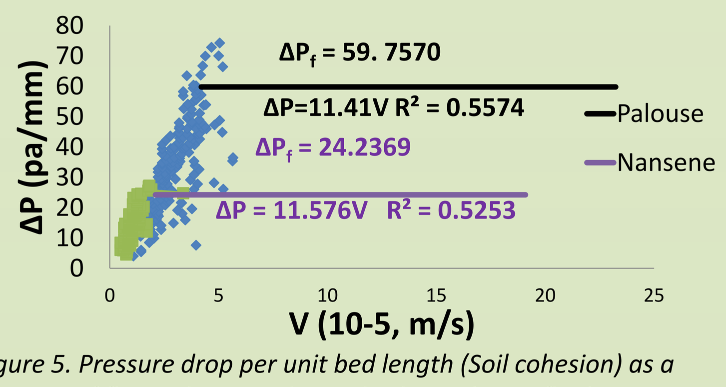


Figure 5. Pressure drop per unit bed length (Soil cohesion) as a function of flow velocity within soil column during fluidization experiment

SUMMARY AND CONCLUSION

(1)Saturated condition had the largest runoff discharge rate for both soils.
(2)Nansene had higher sediment discharge rates than Palouse.
(3)Highest and lowest interill and rill erodibility values were obtained for dry conditions and drainage conditions, respectively.
(4) Highest and lowest critical shear values were obtained for Palouse under dry conditon and Nansene under drainage condition, respectively.
(5)Back-calculated USLE-K values for Palouse under different moisture conditions were similar, but significantly different from the WEPP-default K value.
(6) WEPP default K values were highest for both soils.
(7) Drainage condition produced the lowest back calculated K values.
(8)Soil cohesion derived from the FBD confirmed to the back calculated WEPP-K values obtained under the dry, saturated and drainage conditions.
(9)That also clearly confirmed that there is a negative relationship between soil cohesion and erodibility.
(10)Soil organic matter content has a significant role on soil erodibility and mechanical soil cohesion and its function on soil physical properties should have taken into consideration for next generation erosion modelling studies as much as hydrological properties.

Experimental procedure

Determine baseline WEPP model erodibility parameters (K_i, K_r, τ_{cr}) under initially dry, saturated and drainage conditions (From WEPP interrill equation (Foster et al., 1995) NSERL Report #10, Chapter 11)

Interrill experiment (rainfall simulation)

Constant head water supply system to saturate soil boxes

9% slope steepness Soil boxes: 100 cm long; 60 cm wide; 5 cm soil dept; 35 cm gravel dept for infiltration

$$K_i = D_i / [I_e \sigma_{ir} (1.05 - 0.85\, e^{-4 sin \Omega})]$$

Rill experiment (V-shaped mini flume)

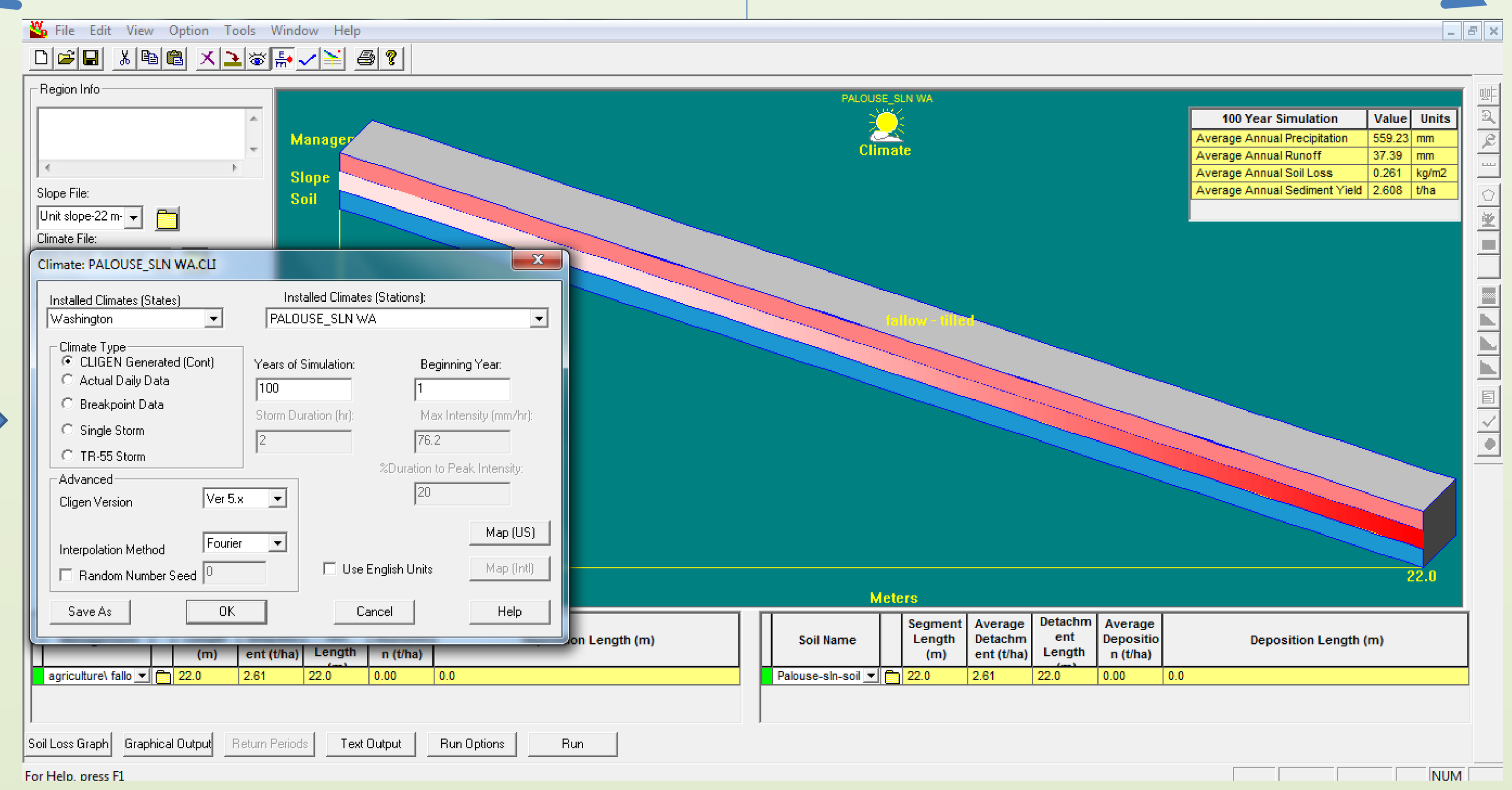
$$K_r = D_c / (\tau - \tau_{cr})$$

3% slope steepness Flume sizes: 0.046 cm wide; 0.5 m long and 0.12 m dept (0.05 m soil dept); Micro-flow meter (FTB300, Omega)

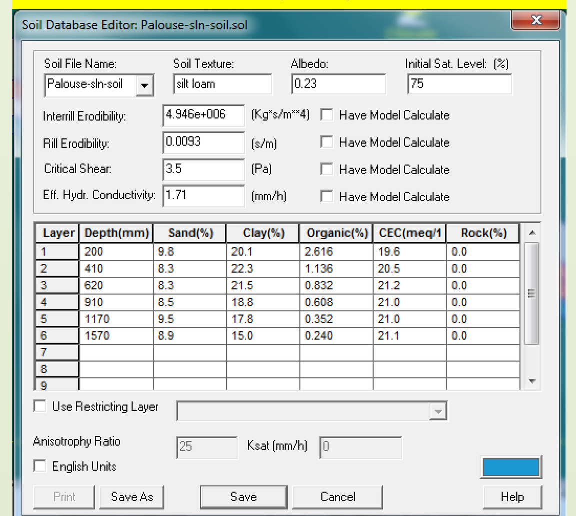
Obtained:
- ✓Dry-K_i
- ✓Saturated-K_i
- ✓Drainage-K_i

Obtained:
- ✓Dry-Kr , Dry-τ_{cr}
- ✓Saturated-Kr , Saturated-τ_{cr}
- ✓Drainage-Kr , Drainage-τ_{cr}

Climate: 100 years of synthetic weather input, Cligen v5.x, fournier interpolation between months.
Slope: unit slope, 22 m long, a uniform 9% gradient



Soil input file



WEPP-Soil loss ➡ **USLE-K=** $\frac{\text{WEPP Soil loss}}{\text{USLE - R}}$

Determine soil cohesion with fluidized bed technique (FBD) proposed by Nouwakpo et al. (2010)

a solid particle bed behaves as a fluid by the introduction of a pressurized fluid in the pore space of the particle bed…

Experimental procedure proposed by Nouwakpo et al. (2010):

✓ The hydraulic head at the bottom of the test bed was incrementally increased by raising the water supply tank in 4-mm increments.

✓ The flow rate was measured by collecting and weighing the volume of water exiting the chamber in a given time and recorded presure between top and bottom of the test bed.

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Rererences

Foster, G. R., D. 11: Hillslope erosion component. In: USDA Water Erosion Prediction Project Hillslope and Watershed Model Documentation. D. C. FlaC. Flanagan, M. A. Nearing, L. J. Lane, L. M. Risse, and S. C. Finkner. 1995. Chapter nagan and M. A. Nearing, eds. NSERL Report No. 10. West Lafayette, Ind.: USDA-ARS National Soil Erosion Research Laboratory.

Nouwakpo, S.K., C. Huang, L. Bowling, and P. Owens. 2010. Impact of vertical hydraulic gradient on rill erodibility and critical shear stress. Soil Sci. Soc. Am. J. 74:1914–1921. doi:10.2136/sssaj2009.0096