CORRIGENDUM TO "ESTIMATING WEPP CROPLAND ERODIBILITY VALUES FROM SOIL PROPERTIES"

Collection Corrigendum

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HIGHLIGHTS

- Interrill erodibility K_i values presented in Elliot and Flanagan (2023) were incorrect, and correct values are given.
- Interrill erodibility can be estimated from a soil's sand, very fine sand, and clay contents.

ABSTRACT. *In Elliot and Flanagan (2023), the interrill and rill soil erodibility of 36 cropland soils was reported, along with correlations among soil erodibility and other soil properties, and equations to estimate erodibility from readily measured soil properties. Early versions of the Water Erosion Prediction Project (WEPP) model had linked interrill detachment rate to the square of the rainfall intensity and an interrill soil erodibility constant K_{i1}. By the time the WEPP model was released for general use in 1995, the developers had changed the interrill detachment rate to be a function of the product of rainfall intensity and runoff and a different interrill erodibility constant, K_{i2}. The interrill erodibilities (K_{i2}) with this altered relationship were not the same as K_{i1} values developed to support earlier releases of the WEPP model. The authors, when reviewing some of the past literature supporting Elliot and Flanagan (2023), had mistakenly reported K_{i2} values when the numbers reported were in fact K_{i1} values. A closer examination of the entire data set and the identification of a published source for the correct K_{i2} values confirmed this mistake. This corrigendum reports the corrected K_{i2} values, the correlation of those revised values with other soil properties, and confirmation of a 1995 regression equation relating K_{i2} to three readily measured soil properties: sand content, very fine sand content, and clay content. The coefficient of determination for the 1995 regression equation was 0.80. We recommend that all references to K_{i2} in Elliot and Flanagan (2023) be changed to K_{i1} except the discussion about the findings of Mirzaee and Ghorbani-Dashtaki (2021), discussion about K_{i2} in Alberts et al. (1995), and equations 2 and A16. A marked up copy of Elliot and Flanagan (2023) showing these changes can be downloaded from https://www.fs.usda.gov/rm/pubs_journals/2023/rmrs_2023_elliot_w001_corr.pdf.*

***Keywords**. Cropland Soils, Interrill Erodibility, Water Erosion Prediction Project.*

BACKGROUND

After publishing "Estimating WEPP Cropland Erodibility Values from Soil Properties" (Elliot and Flanagan, 2023), the authors discovered that they had not used the correct values for the current interrill erodibility K_{i2} required by the WEPP Model. The purpose of this corrigendum is to present the correct K_i values now required by the WEPP model, show the relationships between the K_{i2} values and other soil properties, and confirm a simplified regression model to estimate K_{i2} from measurable soil properties.

Elliot and Flanagan (2023) presented two interrill erosion models that had been applied in the development of the Water Erosion Prediction Project (WEPP) model. In the earliest versions of the WEPP model in 1987 until about 1993, interrill detachment was estimated by:

$$D_i = V\, S_f\, K_{i1}\, I^2 \quad (1)$$

where

D_i = interrill detachment rate (kg m^{-2} s^{-1})
V = vegetation factors
S_f = slope factor
K_{i1} = interrill erodibility for equation 1 (kg s m^{-4})
I = rainfall intensity (m s^{-1}).

When the WEPP model was recoded between 1993 and 1995, the interrill detachment model was altered to:

$$D_i = V\, S_f\, K_{i2}\, I\, q \quad (2)$$

where

K_{i2} = interrill erodibility for equation 2 (kg s m^{-4})
q = runoff rate (m s^{-1}).

Submitted for review on 14 May 2024 as manuscript number NRES 16069; approved for publication as a Corrigendum and as part of the Soil Erosion Research Symposium Collection by Associate Editor Dr. Aaron Mittelstet and Community Editor Dr. Kati Migliaccio of the Natural Resources & Environmental Systems Community of ASABE on 7 August 2024.

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Citation: Elliot, W. J., & Flanagan, D. C. (2024). Corrigendum to "Estimating WEPP cropland erodibility values from soil properties." *J. ASABE, 67*(5), 1241-1244. https://doi.org/10.13031/ja.16069

Elliot and Flanagan (2023) described the field study in detail from which K_{i1} and K_{i2} were derived. Following discussions with colleagues and a closer examination of the values for K_{i1} and K_{i2} in Elliot and Flanagan (2023), we determined that all the cited works from earlier proceedings and published papers in Elliot and Flanagan (2023) were in fact K_{i1}. Values for K_{i2} were categorized by texture in Alberts et al. (1995), but not published for individual soils. Recently, the authors found that values for K_{i2} were reported in the Huffman et al. (2013) textbook as well as the Fifth edition (Fangmeier et al., 2006) and Sixth edition (Huffman et al., 2011) of that textbook. This corrigendum presents the K_{i2} values from Huffman et al. (2013), the correlation coefficients of those values with other erodibility values and soil properties and confirms the accuracy of the predictive equations from Alberts et al. (1995) to estimate K_{i2} from readily measured soil properties. In this corrigendum, we report the last published values for K_{i1} from the literature cited in Elliot and Flanagan (2023), and K_{i2} values from Huffman et al. (2013). We used an Excel spreadsheet to recalculate all the correlation coefficients between K_{i1}, K_{i2}, and other soil properties. All equations, tables, and discussion in Elliot and Flanagan (2023) about interrill erodibility should be read as K_{i1} except equations 2 and A16, the references about K_{i2} in Alberts et al. (1995), and the findings of Mirzaee and Ghorbani-Dashtaki (2021). These changes have been noted in a marked-up copy of Elliot and Flanagan (2023) that can be downloaded from https://www.fs.usda.gov/rm/pubs_journals/2023/rmrs_2023_elliot_w001_corr.pdf.

Results

Table 1c is similar to table 1 in Elliot and Flanagan (2023), except some K_{i1} and all K_{i2} values were changed and are shown in bold. On average, K_{i2} was nearly double the value of K_{i1}. K_{i2} values for coarse-textured soils with lower runoff rates were remarkedly greater than K_{i1}, note soil numbers 24 and 25. Also, soils with a high very fine sand content had a much greater K_{i2} value compared to K_{i1}, like soil numbers 5, 8, and 32. Huffman et al. (2013) did not have a K_{i2} value for soil 3. We observed that the observed value for K_{i2} for soil 6 was much lower than similar silt loam soils, likely due to the high root content as described in Elliot and Flanagan (2023), so we did not include this soil in the subsequent statistical analyses.

The correlation coefficients were recalculated for both K_{i1} and K_{i2} and are presented in table 5c. Correlation between K_{i1} and K_{i2} was weak (r = 0.39). The highest correlation for K_{i2} was with the very fine sand content $VfSa$ (r = 0.59). The soil classification order that was highly correlated with K_{i1} (r = 0.52) was not correlated with K_{i2} (r = 0.07). The saturated base hydraulic conductivity K_b has been added in table 5c as it related to runoff, and it was weakly correlated with K_{i2} (r = 0.29).

With the corrected values for K_{i2}, we could not improve on the K_{i2} predictive equation that was originally proposed in Alberts et al. (1995) for estimating K_{i2} using limited soil properties:

$$\begin{aligned} &\text{For } Sand \geq 30\% \quad K_{i2} = 2.7 + 0.19\ VfSa \quad \text{and} \\ &\text{For } Sand < 30\% \quad K_{i2} = 6.05 - 0.055\ Clay \quad r^2 = 0.80 \end{aligned} \tag{12c}$$

where

K_{i2} = interrill erodibility x 10^{-6} (kg s m^{-4})

$Sand$ = Sand content (0.05 mm – 2 mm dia) of fine fraction (<2 mm dia) (percent)

$VfSa$ = Very fine sand content (0.05 mm – 0.01 mm dia) of fine fraction (<2 mm dia) (percent)

$Clay$ = Clay content (<0.002 mm dia) of fine fraction (<2 mm dia) (percent).

Figure 4c shows the predicted K_{i2} values from equation 12c vs. the updated observed values and one observation from an independent study by Mirzaee & Ghorbani-Dashtaki (2021).

Discussion

The K_{i2} values were originally derived by Laflen in the mid-1990s from the Elliot et al. (1989) field data but were not published until 2006 in Fangmeier et al. (2006). The K_{i1} estimates were made from the last two to four samples collected from the interrill erosion plots recorded in Elliot et al. (1989) when runoff had reached "equilibrium," but Laflen used more points to estimate K_{i2} as equation 2 considered runoff rate as well as rainfall intensity. How many of those points Laflen used is not known, so there is scope to recalculate K_{i2} from the data in Elliot et al. (1989) and quantify the effect of the analytical methods on determining K_{i2}.

Table 5c shows that the revised K_{i2} values were poorly correlated with the K_{i1} values (r = 0.39). However, correlation between K_{i2} and very fine sand was exceptionally high (table 5c; r = 0.59). The correlation with the soil classification order that was high with K_{i1} (r = 0.52) was weak with K_{i2} (r = 0.07). Table 1c shows that K_{i1} and K_{i2} values tended to differ the most on soils that were high in sand content where observed runoff rates were low (soil numbers 24 and 25), or soils high in very fine sand where K_{i2} values were high (soil numbers 5 and 8). The correlation of K_{i2} with saturated hydraulic conductivity (r = 0.29) was not as great as many of the other variables in table 5c that were related to soil texture.

The predictive equation originally proposed by Alberts et al. (1995) considered both sand and very fine sand in the prediction. The coefficient of determination for the simplified predictive equation 12c from Alberts et al. (1995) was greater for K_{i2} (r^2 = 0.80) than for K_r (r^2 = 0.73) or τ_c (r^2 = 0.62) in Elliot and Flanagan (2023).

Of the four outlier points in figure 4c, the overestimation of the Mirzaee and Ghorbani-Dashtaki (2021) was likely due to differences in field methods as discussed in Elliot and Flanagan (2023). Two of the other three overpredictions were Soil 1 (Brenneman, 1988) and Soil 10, which, like soil 6, had not been in fallow the year prior to the experiment, and thus roots in the soil may have reduced the measured interrill erodibility.

Table 1c. Site number, soil series, location, erodibility, and textural properties of WEPP cropland soils with corrected values for K_{i1} and K_{i2} in bold. Definitions of variables and their units were presented in table 2 in Elliot and Flanagan (2023).

No.	Soil Series	Location	Texture	K_{i1}[a]	K_{i2}	K_r	τ_c	*Clay*	*Silt*	*Sand*	*FSi*	*VfSa*	*MSa*	*Rock*	*OC*
1	Clarion	Ames, IA	FSL	2.03	**2.37**	4.6	0.4	18.9	27.2	53.9	14.4	10.9	13.8	4	1.05
2	Monona	Castana, IA	SiL	1.78	**4.76**	7.6	2.8	20.1	74.8	5.1	27	4.9	0	0	1.02
3	Cecil 1[b]	Watkinsville, GA	SaL	1.18	-[c]	8.4	2.2	8.6	16.7	74.7	11.5	5.9	22.4	4	0.55
4	Sharpsburg	Lincoln, NE	SiCL	**1.85**	**3.84**	5.3	3.2	39.8	55.4	4.8	23.9	4.6	0	0	1.85
5	Hersh	Ord, NE	SaL	**3.93**	**9.18**	11.2	1.7	9.6	13.4	77	2.2	32.9	18.2	0	0.49
6	Keith	Albin, WY	SiL	**3.37**	**4.07**			19.3	31.8	48.9	11.3	44	1	0	0.91
7	Amarillo	Big Spring, TX	SaL	**4.12**	**6.78**	45.3	1.7	7.3	7.7	85	2.9	21.1	23.9	0	0.16
8	Woodward	Woodward, OK	L	**4.00**	**10.2**	25	1.3	12.3	39.9	47.8	9.1	39	1.1	0.3	0.82
9	Heiden	Waco, TX	C	**1.70**	**3.23**	8.9	2.9	53.1	38.3	8.6	29.3	4.5	1	0	1.36
10	Whitney	Fresno, CA	SaL	**2.74**	**1.83**	23.3	4.7	7.2	21.7	71.1	9.7	8.1	19.2	4	0.19
11	Academy	Fresno, CA	SaL	**2.88**	**4.15**	5.7	1.6	8.2	29.1	62.7	12.2	20.2	13.7	4	0.41
12	Los Banos	Los Banos, CA	SiL	**2.50**	**3.64**	0.6	2.1	43	41.0	16	21.1	11.3	0.8	0	1.47
13	Portneuf	Twin Falls, ID	SiL	1.26	**5.44**	10.6	3.1	11.1	67.4	21.5	29.4	19.3	0.5	0	0.72
14	Nansene	Dusty, WA	SiL	**3.12**	**5.34**	30.7	3.1	11.1	68.8	20.1	30.6	18.1	0.3	0	1.49
15	Palouse	Pullman, WA	SiL	**4.32**	**4.95**	6.6	0.7	20.1	70.1	9.8	30.9	8.8	0.1	0	1.76
16	Zahl	Bainville, MT	L	**3.17**	**5.13**	12.3	3.5	24	29.7	46.3	14.7	12.5	7.2	9	1.69
17	Pierre	Wall, SD	SiC	**2.18**	**3.33**	11.7	4.8	49.5	40.9	9.6	21.4	7.3	0.8	0	1.46
18	Williams	McClusky, ND	L	**2.94**	**4.99**	4.5	3.4	26	32.4	41.6	17.5	11.5	8.7	5	1.79
19	Barnes	Goodrich, ND	L	**1.71**	**5.17**	3.3	2.3	24.6	36.0	39.5	20.6	12.1	6.7	4	3.26
20	Sverdrup	Wall Lake, MN	SaL	**2.11**	**3.44**	10	1.4	7.9	16.8	75.3	9.4	3.7	27.3	0.3	1.28
21	Barnes	Morris, MN	L	1.60	**4.92**	6.3	4	17	34.4	48.6	16.5	11.4	10.2	6	1.98
22	Mexico	Columbia, MO	SiL	**2.97**	**4.66**	3.6	0.7	26	68.7	5.3	33.1	1.1	1.5	0	1.56
23	Grenada	Como, MS	SiL	**2.63**	**4.94**	7.3	4.5	20.2	77.8	2	36.4	1.5	0.2	0	1.27
24	Tifton	Tifton, GA	Sa	**0.77**	**5.28**	11.3	3.5	2.8	10.8	86.4	4.8	13.3	26.2	23	0.46
25	Bonifay	Tifton, GA	Sa	**0.87**	**5.84**	17.9	1	3.3	5.5	91.2	3.1	16.2	18.6	1	0.32
26	Cecil 2[b]	Watkinsville, GA	SaL	**1.86**	**3.94**	3.8	4.5	19.8	15.6	64.6	9.3	5.9	18.5	6	0.70
27	Hiwassee	Watkinsville, GA	SaL	1.88	**3.55**	10.3	2.3	14.7	21.6	63.7	15.3	4.3	19.2	3	0.83
28	Gaston	Salisbury, NC	CL	**2.04**	**4.17**	4.9	4.4	39.1	25.4	35.5	17.6	7.5	10.1	0.3	1.12
29	Opequon	Flintstone, MD	CL	**3.20**	**3.86**	3.5	6.3	31.1	31.2	37.7	22.8	5.9	9.6	14	1.42
30	Frederick	Hancock, MD	C	**2.48**	**5.14**	8.4	6.6	16.6	58.3	25.1	39.4	5.2	6.6	14	1.32
31	Manor	Ellicott City, MD	L	**2.69**	**4.09**	5.4	3.6	25.7	30.7	43.6	23.4	7.1	10.6	8	0.96
32	Caribou	Presque Isle, ME	L	**1.45**	**4.78**	4.5	4.3	12.2	40.8	47	25.6	11.5	7.8	47	2.28
33	Collamer	Ithaca, NY	SiL	**3.46**	**5.23**	24.1	6.4	15	78.0	7	47.5	4.6	0.7	0.3	1.01
34	Miamian	Dayton, OH	L	**1.65**	**4.36**	9.6	5.5	25.3	44.1	30.6	28.6	6.4	7.4	3	1.75
35	Lewisburg	Columbia, IN	CL	**2.47**	**4.82**	5.9	3.4	29.3	32.2	38.5	19.4	10.9	7.2	6	0.87
36	Miami	Waveland, IN	SiL	**1.97**	**4.78**	9.5	3.3	23.1	72.7	4.2	36.9	2	0.8	0	0.82

[a] Units for all properties are presented in table 2 in Elliot and Flanagan (2023).

[b] "Cecil 1" was a "non-eroded" site, and "Cecil 2" was an "eroded" site, but both soils were classified as "Cecil."

[c] K_{i2} data were not available for Cecil 1.

Table 5c. Correlation coefficients (r) between K_{i1}, K_{i2}, K_r, τ_c, and *clay* content and select soil properties. Soil property descriptions and units for variables were described in table 2 in Elliot and Flanagan (2023). The soil properties with the greatest correlation coefficient for each erodibility value are highlighted.

Property	K_{i1}	K_{i2}	K_r	τ_c	*Clay*	Property	K_{i1}	K_{i2}	K_r	τ_c	*Clay*
K_{i1}	**1.000**	**0.390**	0.350	-0.181	-0.029	*N*	**-0.001**	**-0.105**	-0.398	0.194	0.515
K_{i2}	**0.390**	**1.000**	0.395	-0.147	-0.369	*Ca*	**0.190**	**-0.241**	-0.256	-0.042	0.563
K_r	**0.350**	**0.395**	1.000	0.049	-0.417	*Na*	**0.132**	**-0.082**	0.196	-0.082	0.244
τ_c	**-0.181**	**-0.147**	0.049	1.000	0.196	*Mg*	**-0.091**	**-0.146**	-0.343	-0.061	0.509
Clay	**-0.029**	**-0.369**	-0.417	0.196	1.000	*CEC*	**0.044**	**-0.242**	-0.338	-0.073	0.808
Silt	**0.153**	**0.002**	-0.076	0.209	0.222	*SAR*	**0.096**	**-0.135**	0.150	-0.052	0.032
Sand	**-0.108**	**0.169**	0.252	-0.256	-0.634	*Cond*	**0.224**	**-0.004**	-0.075	-0.321	0.119
VfSa	**0.400**	**0.594**	0.249	-0.558	-0.327	*$CaCO_3$*	**-0.210**	**-0.107**	-0.035	0.002	0.365
MSa	**-0.212**	**-0.036**	0.201	-0.070	-0.549	*Ag Stab*	**-0.091**	**-0.279**	-0.099	0.256	0.579
M	**0.356**	**0.398**	0.168	-0.083	-0.227	*SpSf*	**-0.020**	**-0.324**	-0.391	0.045	0.899
USLE-K Factor	**0.352**	**0.296**	0.183	-0.008	-0.166	*15Bar*	**-0.037**	**-0.353**	-0.477	0.174	0.964
K_b[a]	**-0.186**	**0.294**	**0.321**	**-0.257**	**-0.637**	*PL*	**0.074**	**0.168**	-0.171	0.177	0.101
Rock	**-0.277**	**-0.045**	-0.189	0.314	-0.198	*LL*	**0.028**	**0.043**	-0.174	-0.061	0.147
OC	**-0.082**	**-0.131**	-0.408	0.156	0.437	*MC*	**0.217**	**0.399**	0.118	0.059	0.029
OM	**0.028**	**-0.210**	-0.395	0.186	0.410	*Slope*	**0.114**	**0.064**	-0.096	0.601	0.058
WD Clay	**-0.143**	**-0.341**	-0.350	0.495	0.698	*Order*	**0.518**	**0.073**	0.054	-0.088	0.025
WDClay/Clay	**-0.418**	**-0.193**	-0.002	0.451	-0.183	*Miner*	**0.206**	**-0.017**	-0.161	-0.151	0.559
CEC/Clay	**0.124**	**0.187**	0.091	-0.360	-0.161	*Miner/Clay*	**0.051**	**0.416**	0.490	-0.300	-0.731
Fe	**-0.056**	**-0.274**	-0.355	0.430	0.426	*VSJ*	**-0.272**	**-0.300**	-0.116	0.075	0.056
Al	**-0.113**	**-0.200**	-0.373	0.373	0.291						

[a] K_b is the saturated hydraulic conductivity (mm h^{-1}).

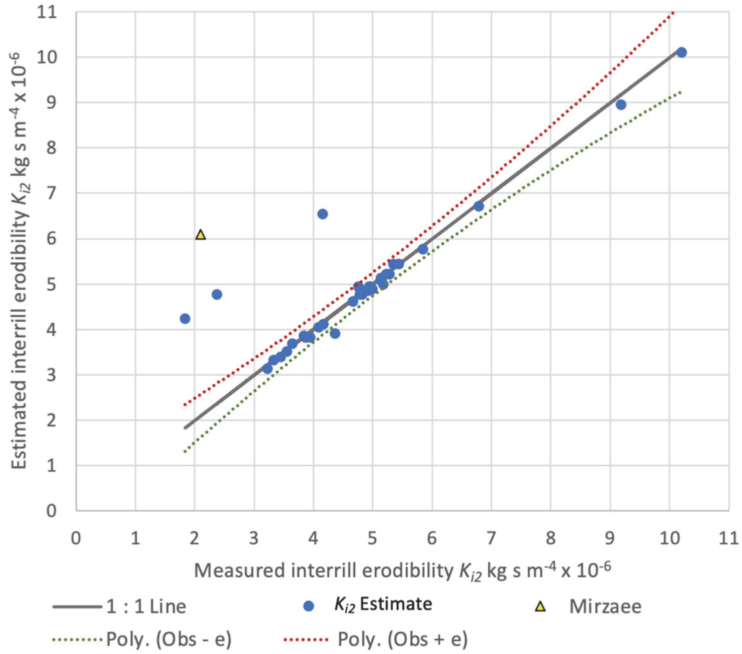

Figure 4c. Estimated interrill erodibility K_{i2} from equation 12c and K_{i2} confidence intervals vs. observed cropland interrill erodibility for WEPP croplands (Huffman et al., 2013) with blue dots for estimated values, red dotted line is upper confidence limit, and green dotted line is lower confidence limit (α = 0.05). Predicted vs. observed K_{i2} value from Mirzaee and Ghorbani-Dashtaki (2021) is shown with a triangle. Solid line is 1:1 line. In legend, "e" is error estimate for confidence limits (Snedecor and Cochran, 1972).

SUMMARY

We have presented a revised set of values for interrill erodibility, correcting a mistake that was made in Elliot and Flanagan (2023). The new interrill erodibility values are larger, reflecting a change in the internal WEPP interrill erosion model. The revised values confirm the validity of the predictive equations developed for interrill erodibility in Alberts et al. (1995).

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