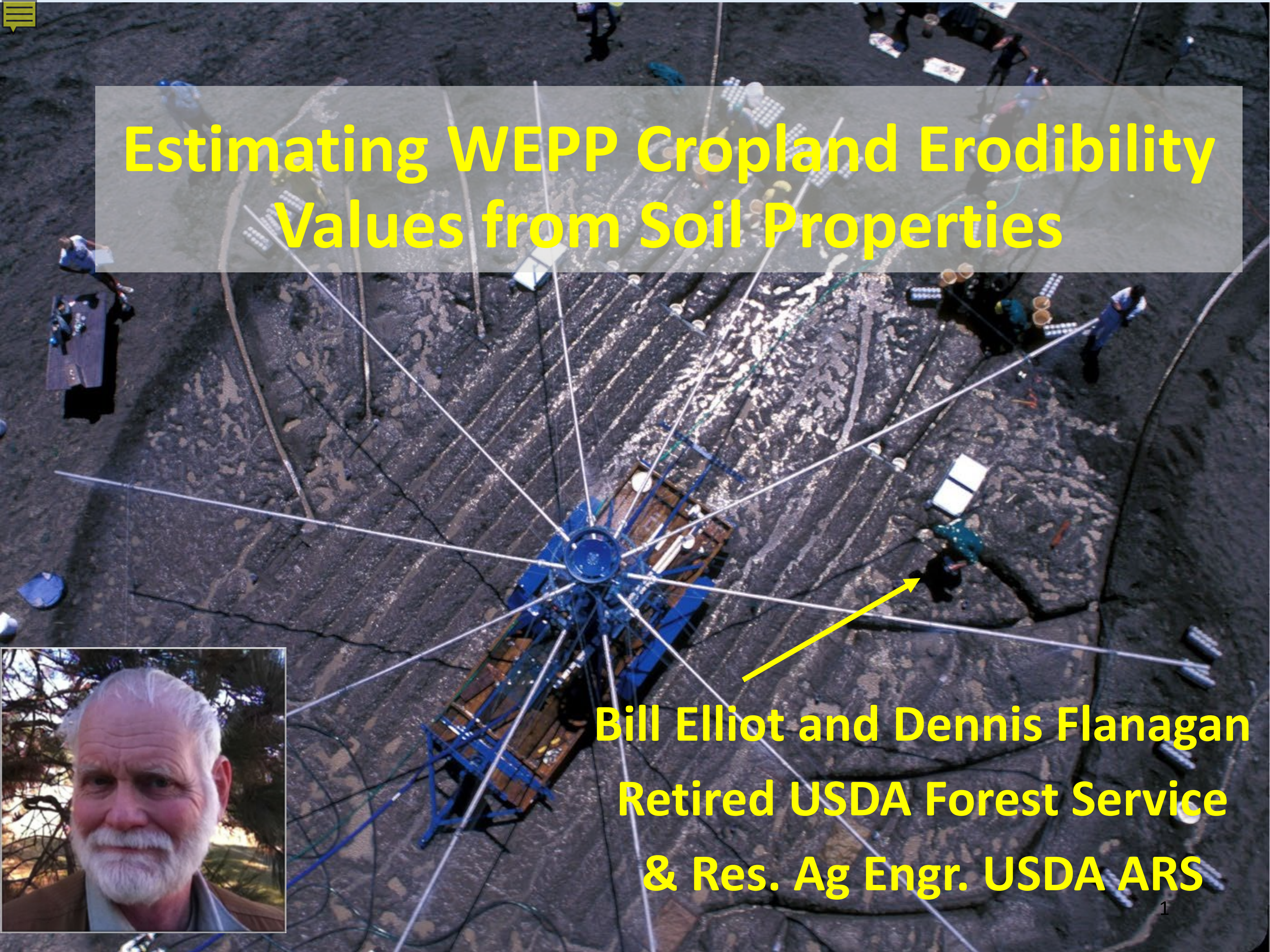

Estimating WEPP Cropland Erodibility Values from Soil Properties

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Retired USDA Forest Service
& Res. Ag Engr. USDA ARS

What's in this Presentation?

- History of the **Water Erosion Prediction Project (WEPP)**
- WEPP Cropland Field Studies
- Correlations between Soil Erodibility and Soil Properties
- Regressions to Estimate Erodibility from Soil and Site Properties
- Potential for Further Studies

Some WEPP History and Features...

- In the 1980s the USDA ARS and other agencies and universities developed a physically based soil erosion model
- Model included
  - Daily weather, hydrology & plant growth
  - Rill and Interrill erosion processes
  - Single storm and long-term average annual runoff and erosion estimates
- One of the WEPP requirements was a nonexistent database of rill and interrill soil erodibility values

Erodibility Equations in WEPP

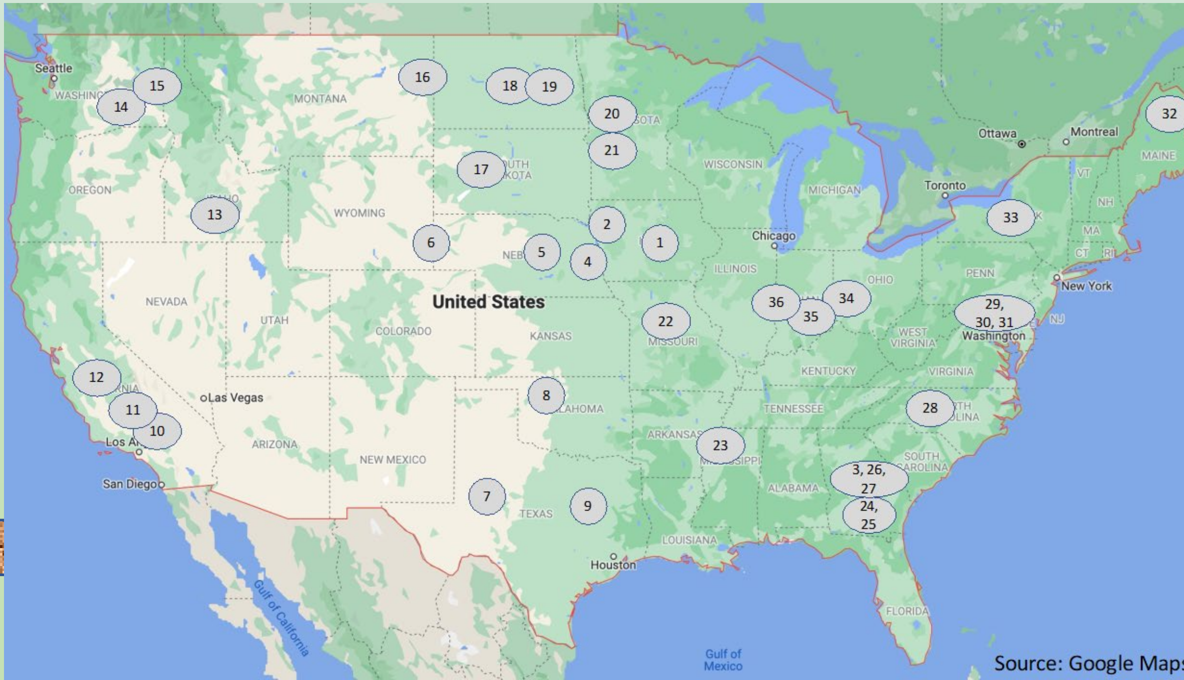
- Interrill Erodibility:
  - Pre 1989
    - $D_i = V\ S_f\ \boldsymbol{K_{i1}}\ i^2$
  - Post 1990
    - $D_i = V\ S_f\ \boldsymbol{K_{i2}}\ i\ q$
- Rill Erodibility
  - $D_r = D_c\left(1 - \frac{G}{T_c}\right) = \boldsymbol{K_r}\ (\tau - \boldsymbol{\tau_c})\left(1 - \frac{G}{T_c}\right)$
- But the erodibility properties, $\boldsymbol{K_i}$, $\boldsymbol{K_r}$ and $\boldsymbol{\tau_c}$ were not known for any soil.

The **Big** Research Question:

How can we estimate $\boldsymbol{K_i}$, $\boldsymbol{K_r}$ and $\boldsymbol{\tau_c}$ from other measurable soil properties for many of the 20,000 soils in the U.S.A.?

What Soils were Studied?

- To build a soil erodibility database for WEPP, a field study was planned
  - 36 sites covering the USA
  - 6 Soil orders
  - Wet and Dry, and Warm and Cool climates
  - Glacial, Aeolian, Alluvial, young and weathered soils



How did we Measure Interrill Erodibility?

- Tilled ridged plots on fallow ground and formed plots
- Simulated Rainfall (~60 mm/h)
- Collected timed runoff with sediment in bottles
- Weighed ➔ Dried ➔ Weighed sample bottles
- Solved the Interrill Erodibility for $\boldsymbol{K_i}$
  - $K_i = \frac{D_i}{S_f\, i\, q}$

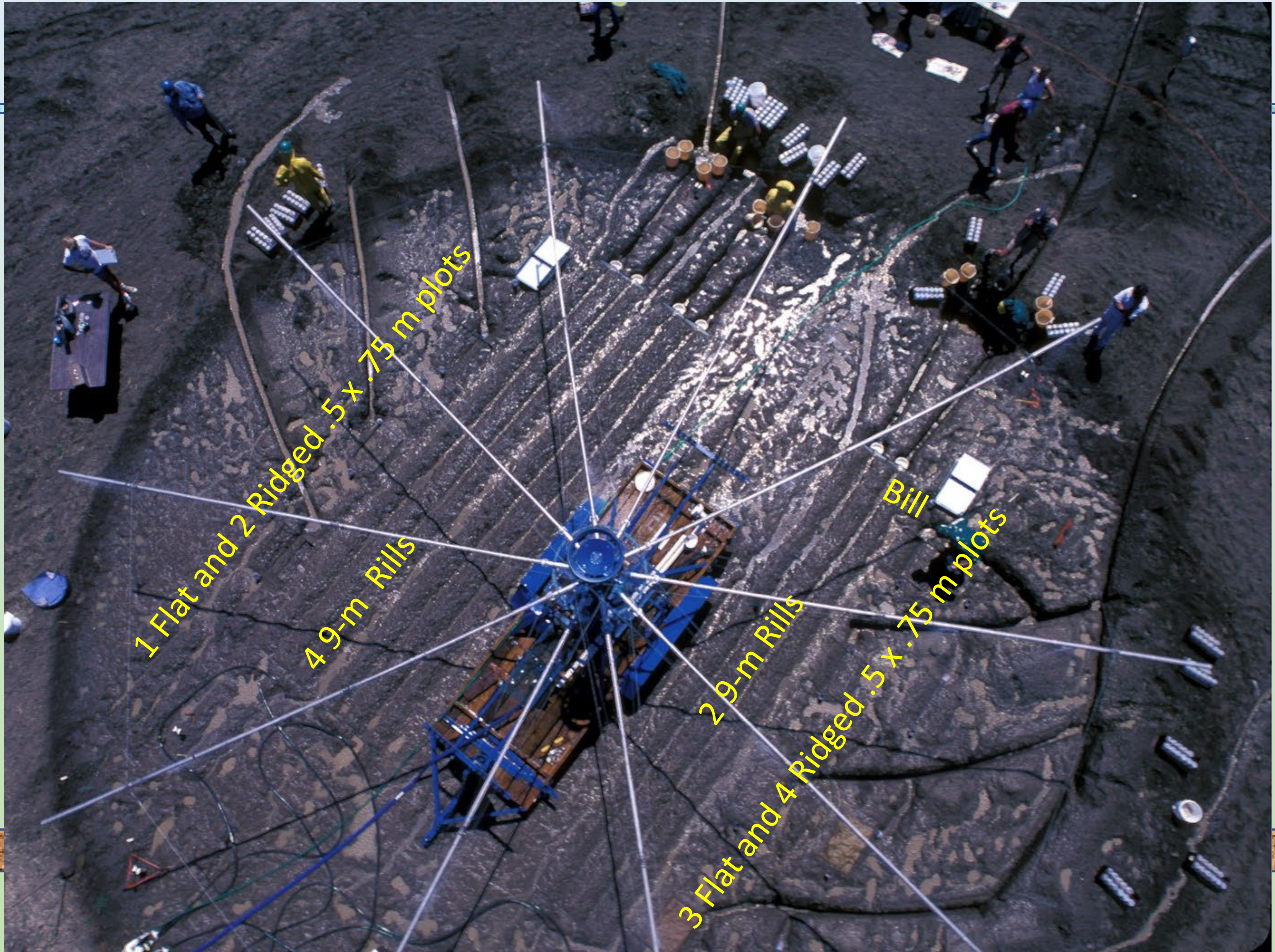
Interrill plots

Bill collecting interrill samples

How was rill erodibility measured?

- Six rills 9-m long were formed with a ridging tool and borders installed
- During simulated rainfall, additional flows of ~0, 7, 14, 21, 28 & 35 l/min were added
  - Two timed runoff samples were collected from each flow rate
  - Samples bottles were weighed, dried and reweighed to calculate runoff and sediment flux
  - Hydraulic shear was calculated for each runoff rate from rill flow velocities and rill cross sectional shapes
- $\boldsymbol{K_r}$ and $\boldsymbol{\tau_c}$ were calculated from $\boldsymbol{D_c}$ vs shear regressions, considering sediment in transport

Bird’s Eye View of a Study Site



Collecting Rill Erosion Data

Measuring Rill Velocity with stopwatch and fluorescent dye

Sample bottles to measure sediment concentration and
Timed bucket masses to measure runoff rates

How were Soil Properties Measured?

- On each site, local SCS soil survey specialists dug one 2-m deep pit in the center of the site, and 4 1-m pits nearer the perimeter
  - Soils were analyzed at the SCS soil survey laboratory in Lincoln, NB
- During the erosion experiment, soil strength measurements were made on rill sides and bottoms, and on an external plot
  - Pocket penetrometer with big head
  - Handheld torvane shear device with big vane
  - Fall cone penetrometer

Findings Presented as Proceedings

- Correlation and regression relationships were derived relating soil erodibility to soil properties

’90b focus on mineralogy & geomorphology

‘88 1988 sites only progress report

’93 focus on limited properties with nomographs

‘89 focus on SCS soil properties

’90a focus on soil strength

’95 focus on texture only

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Canadian Society of Agricultural Engineering

EFFECT OF SOIL PROPERTIES ON SOIL ERODIBILITY

Paper No. 90-2009
AN ASAE MEETING PRESENTATION

PREDICTING SOIL ERODIBILITY

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SUMMARY:
Rill and interril erodibility, and measured soil physical, chemical, and mechanical properties for thirty-three USDA-ARS WEPP soils located in twenty states are presented. Regression equations to predict erodibility values from measured properties are given.

KEYWORDS:
Erosion, Soil Conservation, Soils

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Paper No. 902557
AN ASAE MEETING PRESENTATION

PREDICTING SOIL ERODIBILITY FROM SOIL PROPERTIES INCLUDING CLASSIFICATION, MINERALOGY, CLIMATE, AND TOPOGRAPHY

Paper No. 932046
AN ASAE/CSAE MEETING PRESENTATION

SOIL ERODIBILITY NOMOGRAPHS FOR THE WEPP MODEL

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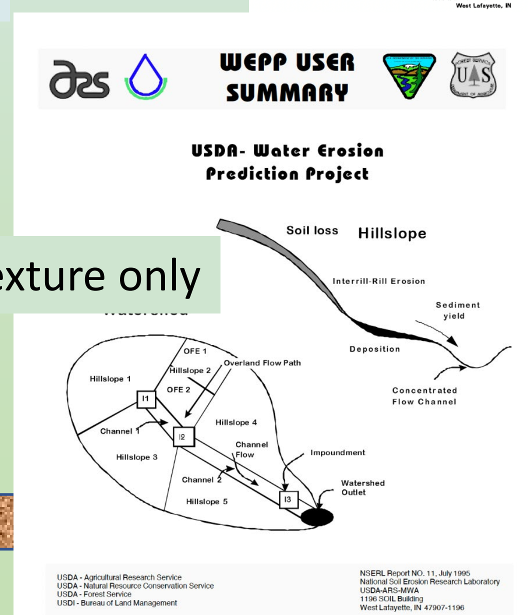


Best Correlation Coefficients

K_i

Property	r
Soil Order	0.52
WD Clay/Clay	-0.42
K-Factor	0.36
Very Fine Sand	**0.37**

K_r

Property	r
Mineralogy/Clay	0.49
Clay Content	-0.42
Organic Carbon	-0.41
Very Fine Sand	**0.25**

τ_c

Property	r
Site Slope	0.60
WD Clay/Clay	0.45
CEC/Clay	-0.36
Very Fine Sand	**-0.56**

Very Fine Sand was the only property that correlated with all three erodibility parameters

Regression Equation Conundrum

Should we seek erodibility predictive equations with

A) the best regression coefficients (r^2) with less common soil properties

or

B) fewer, more common soil properties with lower r^2 values?

A couple of Equations for Estimating $\boldsymbol{K_i}$

- A) Elliot et al. ’90b, considering mineralogy & geomorphology

For soils with smectitic clays (swelling):

$$K_i = 0.44 + 1.728\,Cond + 2.79 \times 10^{-3} \left(\frac{WDSilt^3}{FSi^2}\right)$$

For soils with kaolinitic clays (non swelling):

$$K_i = -1.2 + 0.71 \log_e \left[\frac{(Ca+Mg+Na)^2}{Mg}\right] + 1.1 \log_e \left[\frac{Clay^2}{SpSf \times WDClay}\right] \quad r^2 = 0.79$$

Or

- B) ’95 WEPP User Summary

For soils with *Sand* > 30%: $K_i = 2.728 + 0.1921\,VfSa$

For soils with *Sand* ≤ 30%: $K_i = 6.054 - 0.05513\,Clay$ **r^2=0.24**

A couple of Equations for Estimating $\boldsymbol{K_r}$

- A) Elliot et al. '90a, focus on soil properties

$$K_r = 8.661 + 0.00212\, M + 1.36 \frac{Sand}{100 - Sand} - 0.302\, LL + 1.47 \times 10^{-12} Al^{-8} Mg^{-4}$$

$r^2 = 0.76$

Or

- B) '95 WEPP User Summary

For soils with *Sand* > 30%: $K_r = 1.97 + 0.3\, VfSa + 38.63\, e^{(-1.84\, OM)}$

For soils with *Sand* ≤ 30%: $K_r = 6.9 + 134\, e^{(-0.2\, Clay)}$ **r^2=0.55**

Seven sets of equations are in the paper.

Some Interesting Findings

- Degree of soil weathering is important for estimating $\boldsymbol{K_i}$
- Texture is important for estimating $\boldsymbol{K_r}$
- Plot steepness is useful for estimating $\boldsymbol{\tau_c}$
- USLE ***K-factor*** was a poor predictor of WEPP soil erodibility
  - It is more highly correlated with hydraulic conductivity than WEPP erodibility variables

Points to Ponder

- Should simple or complex equations be used, knowing the coefficient of variation for erodibility (standard deviation ÷ mean) is 30%?
- Should we consider variability of soil properties in the analysis?
  - For each site, There were 5 SCS pits, 6 rill plots and 6 interrill plots.
- Weathering is important for interrill erosion
  - What is the best way to quantify weathering?
- Should more soils be added to the database?

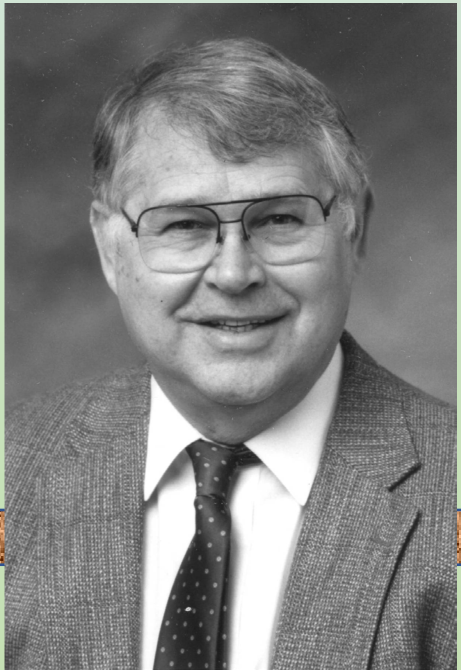
Research Opportunities

- There is an opportunity to expand the soil database
  - More soils with calcium carbonate
  - More aridisols (1 in study),
    andisols and oxisols (none in database)
  - May result in more complicated regression equations
- There is an opportunity to evaluate variability in the erodibility data set and the SCS data set
  - What is the effect of that variability on WEPP's performance?

Some Acknowledgements

- Study was funded by the USDA-ARS
- Dr. Kris Kohl and many other students assisted in data collection and analysis
- The NRCS still maintains the soil properties database accessible on their web site
- John Laflen was the PI on the study, and the major professor of both authors

John briefing field crew at the start of the study



Questions or Comments

- Full paper to be published with symposium collection

John Laflen, PI

ARS Tech, Rich Hartwig Managed every site

Phd Students Kris Kohl and Bill Elliot

Lab truck had bench for weighing bottles and two drying ovens

Undergrad Ann Liebenow worked at every site and compiled the compendium

The End

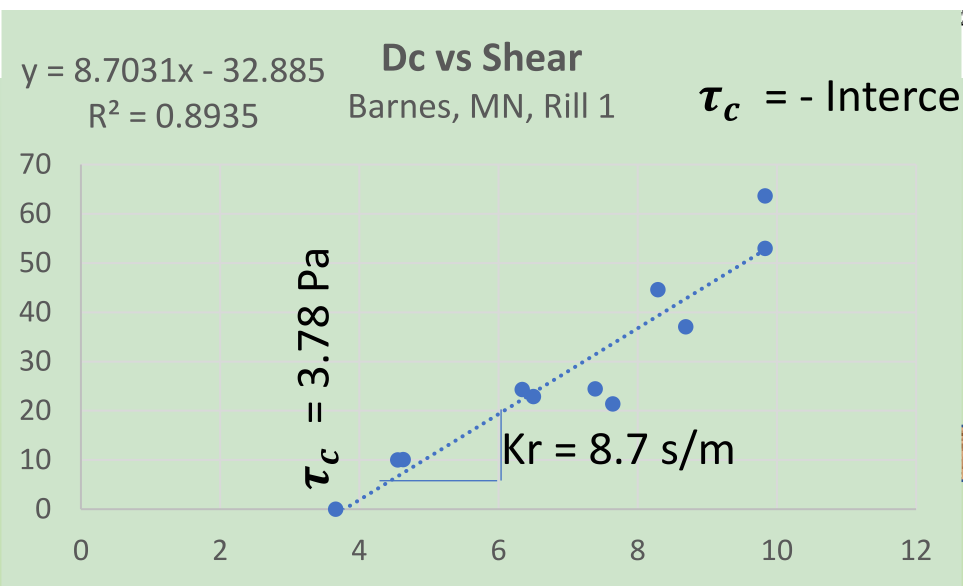
Calculating K_r and τ_c

RILL DATA ANALYSIS   SOIL: BARNES - MN   DATE: AUGUST 9, 1987

Specific Weight = 9786.3 N/m3   Transport Coefficient = 96.20   Kinematic Viscosity = 0.908 x 10-6 m2/s

Velocity Factor = 0.687   Di = 38.02 g/mn/m2

Source	Flow	Conc.	M Vel.	A Vel.	Area	Hrad	Width	Qs	t	Tc	E	Dr	Dc	F	Re
	l/mn	g/l	m/s	m/s	cm2	cm	cm	g/s	N/m2	g/s	<- - -	g/s/m2	- - ->		
Rill 1	slope = 8.3 %														
R+0	3.4	61.4	0.27	0.19	3.05	0.45	6.4	3.5	3.66	43	3.91	2.10	0.00	0.85	919
R+2	9.9	57.3	0.46	0.32	5.24	0.57	7.7	9.5	4.63	74	3.16	10.55	10.08	0.37	1984
R+2	9.6	60.5	0.46	0.32	5.07	0.56	7.7	9.7	4.55	72	3.16	10.86	10.01	0.37	1949
R+4	16.9	72.5	0.51	0.35	8.05	0.78	9.0	20.4	6.34	138	2.62	22.70	24.31	0.41	3010
R+4	17.7	65.3	0.51	0.35	8.41	0.80	9.0	19.2	6.50	143	2.62	21.20	22.86	0.42	3087
R+6	22.1	62.1	0.52	0.36	10.30	0.91	10.3	22.8	7.39	198	2.21	22.53	24.46	0.46	3580
R+6	22.9	52.6	0.52	0.36	10.70	0.94	10.3	20.1	7.64	208	2.21	19.56	21.41	0.48	3698
R+8	27.3	97.9	0.50	0.34	13.26	1.02	11.5	44.6	8.29	265	1.89	41.02	44.62	0.56	3859
R+8	29.1	77.5	0.50	0.34	14.12	1.07	11.5	37.6	8.69	284	1.89	34.31	37.07	0.59	4048
R+10	37.2	110.9	0.54	0.37	16.73	1.21	12.8	68.8	9.83	380	1.64	58.02	63.63	0.57	4944
								2	9.83	380	1.64	48.84	53.00	0.57	4944



τ_c = - Intercept/slope = 3.78 Pa