SEASONAL CHANGE OF WEPP ERODIBILITY PARAMETERS ON A FALLOW PLOT

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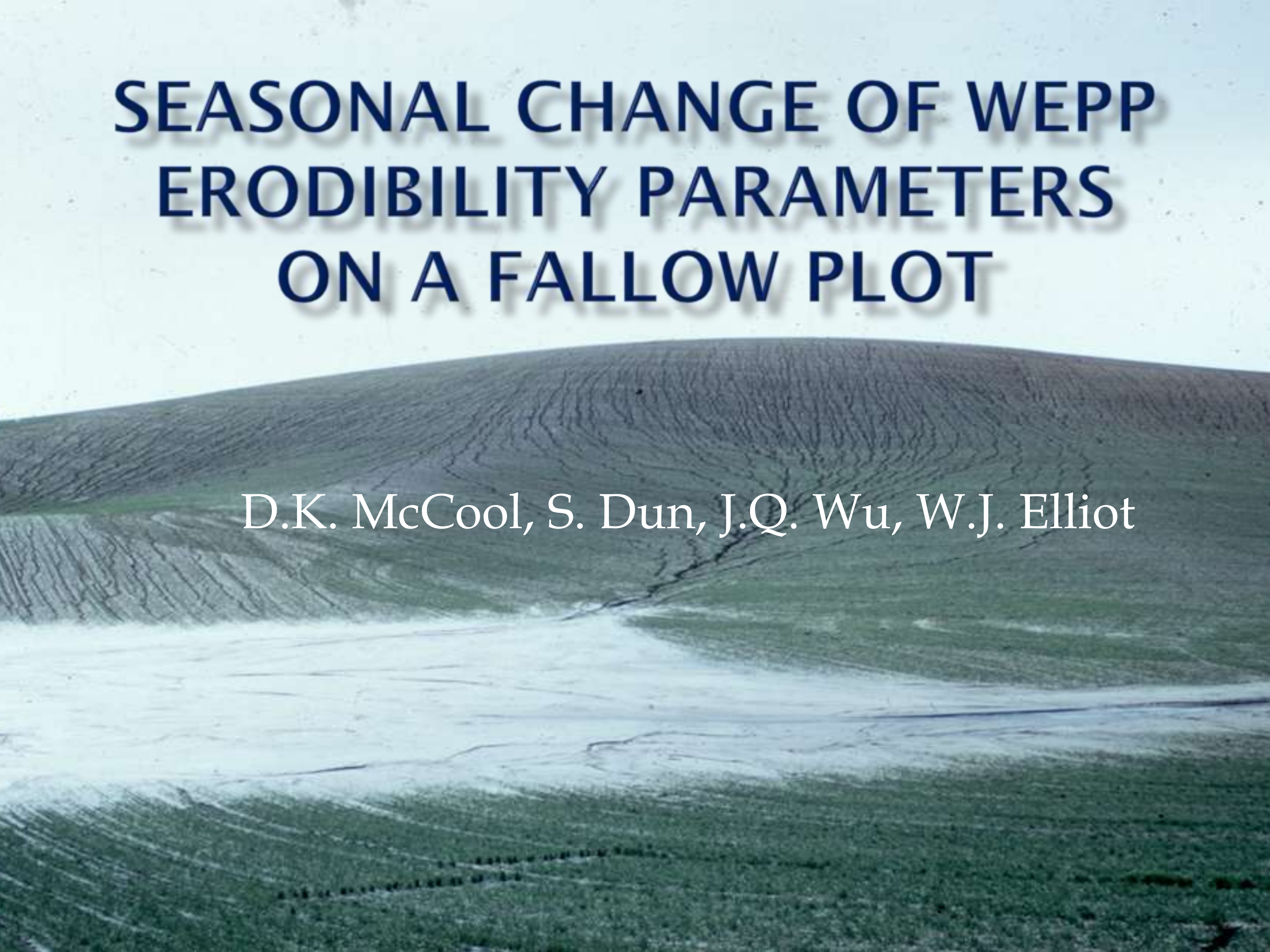


Introduction

- In cold regions, frozen soil has a significant influence on runoff and water erosion
- The freeze-thaw processes reduce soil infiltration capacity, degrade soil cohesive strength, and increase soil erodibility
- In the US Inland Pacific Northwest, major erosion events typically occur during winter from low-intensity rain, snowmelt, or both as frozen soil thaws and exhibits low cohesion

Water Erosion Prediction Project

- WEPP is a physically-based computer program for water erosion; it estimates runoff and sediment yield by simulating major hydrological and erosion process
- WEPP has been widely used for conservation planning on agricultural, range, and forestlands
- Previous applications of WEPP to the Palouse Conservation Field Station (PCFS), southeastern Washington, showed that WEPP reproduced the occurrence of the major observed erosion events but the amount of sediment yield was either under- or over-estimated

Runoff Plots at PCFS

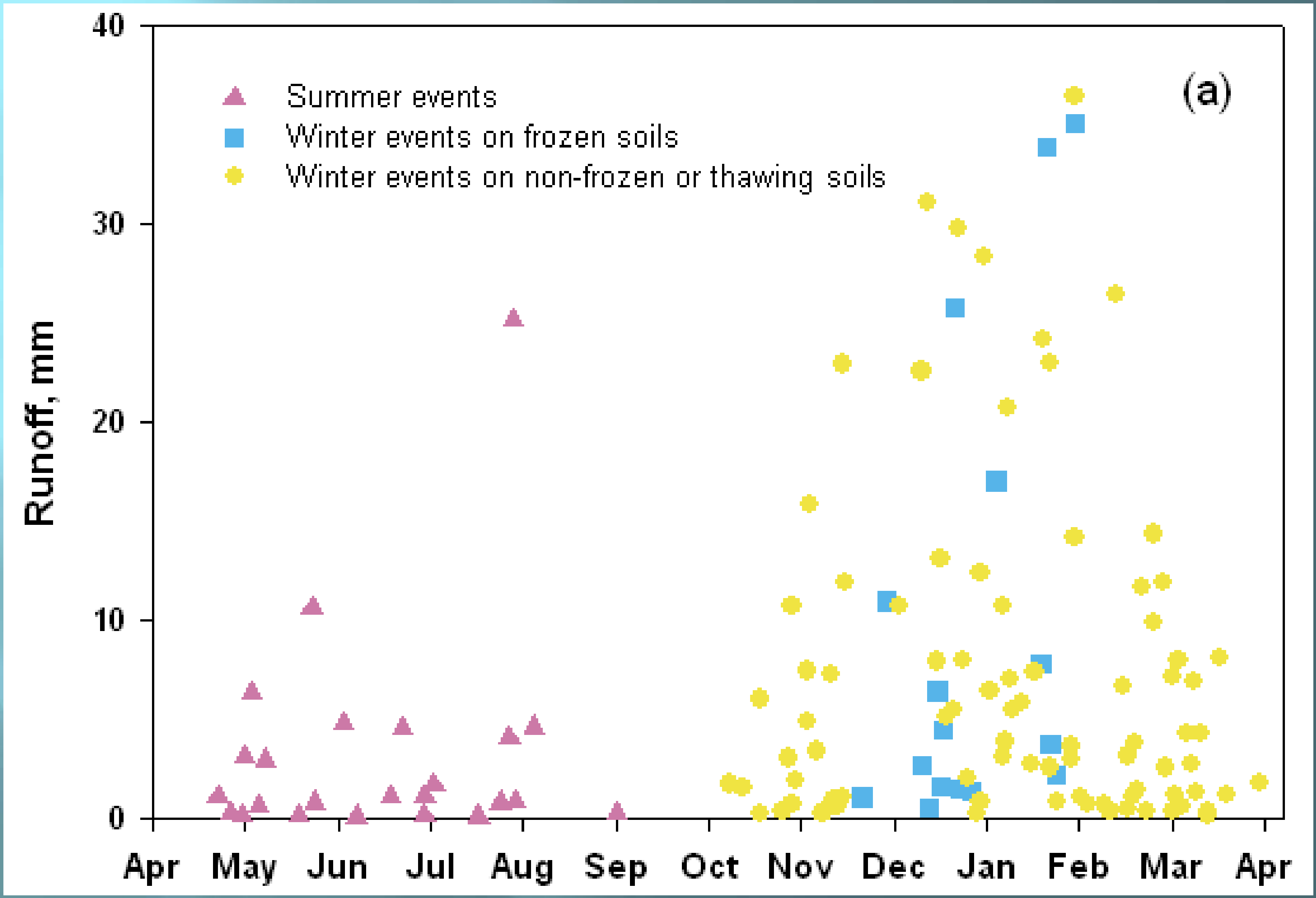
Objective

- To evaluate the seasonal changes of rill erosion parameters on a continuous bare fallow runoff plot at the PCFS in order to improve the representation of the dynamic changes in soil properties in WEPP

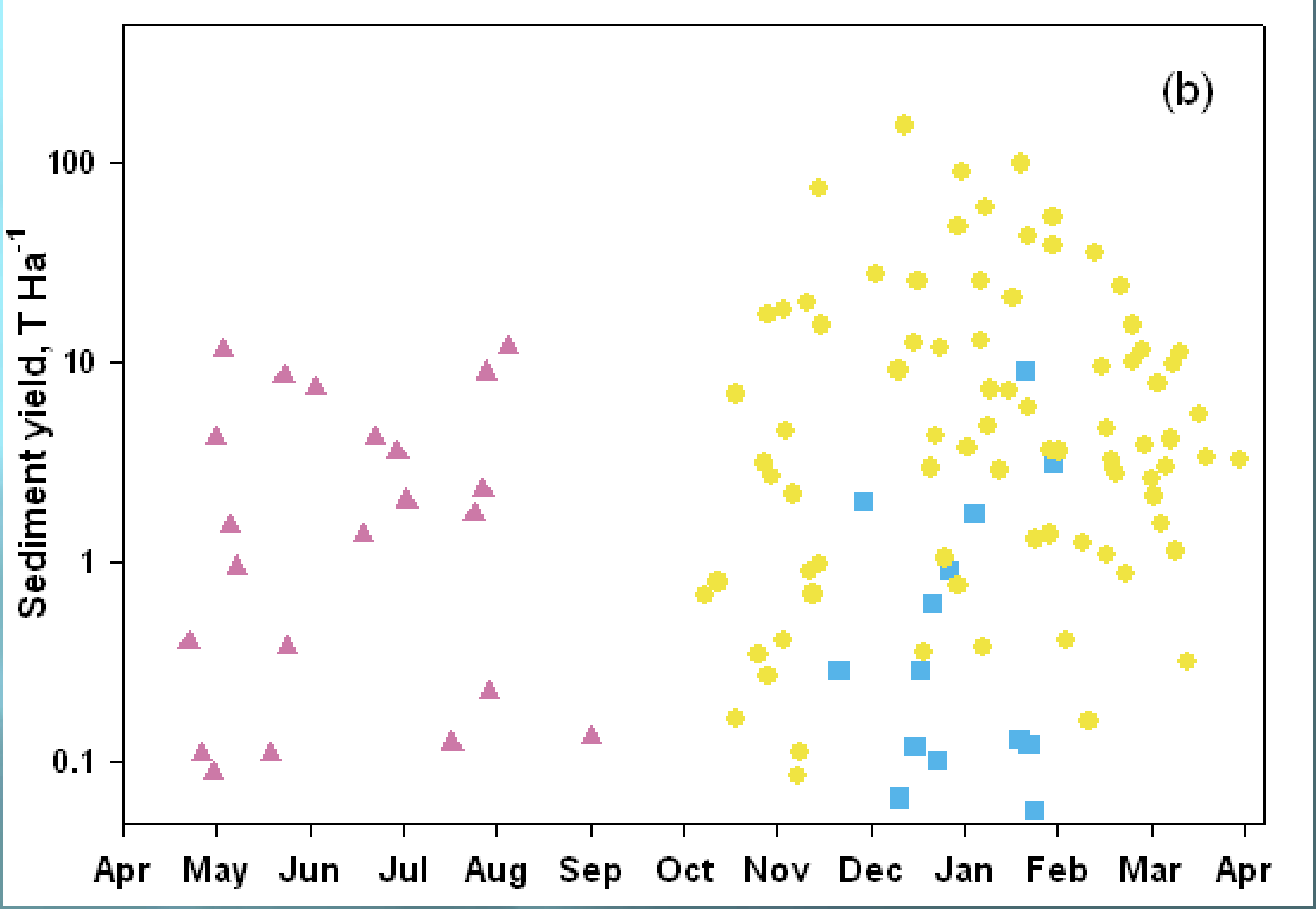
Field Observations

- On plot #13, the chosen continuous bare fallow runoff plot, a total of 126 runoff and erosion events were observed during 1984–1990
  - Summer (May–Oct) events: 24
  - Winter events on frozen soil: 16
  - Winter events on thawing or non-frozen soils: 86
- Mean runoff and sediment yields:
  - Summer events: 3.2 mm, 3.0 t ha^{-1}
  - Winter events on frozen soil: 9.8 mm, 1.2 t ha^{-1}
  - Winter events on thawing or non-frozen soils: 7.1 mm, 13.4 t ha^{-1}

Observed Runoff

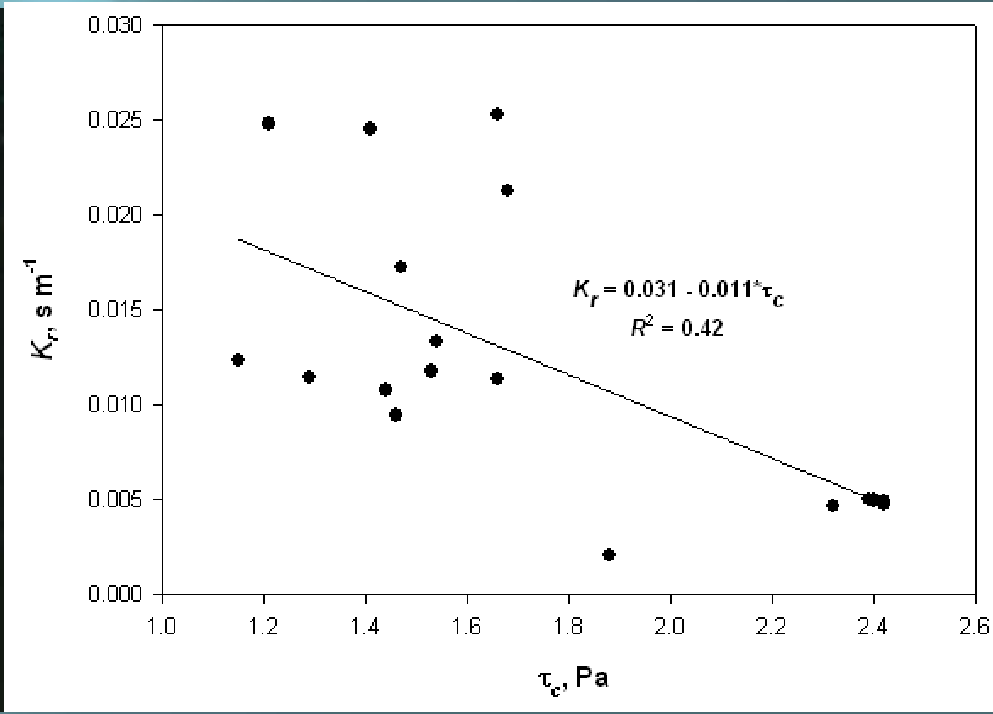


Observed Sediment Yield



Rill Erosion Parameters Measured in Lab Experiments

- A previous flume study on erosion of thawed Palouse soil by Van Klaveren and McCool (2010) showed an inverse relation of critical shear stress vs rill erodibility



Methods

- Single-event simulations using the WEPP model were conducted to reproduce the observed runoff and sediment yield for each event
- Soil effective hydraulic conductivity (K_e) was adjusted to best fit the observed runoff
- Critical shear stress (τ_c) and rill erodibility (K_r) were adjusted to best fit the observed sediment yield, with the relation of τ_c vs K_r following that observed by Van Klaveren and McCool (2010)

WEPP Rill Erosion Model

$$\frac{dG}{dx} = D_f + D_i$$

$$D_f = D_c\left(1 - \frac{G}{T_c}\right) \quad \ldots\ldots \quad G < T_c$$

$$D_c = K_r(\tau - \tau_c)$$

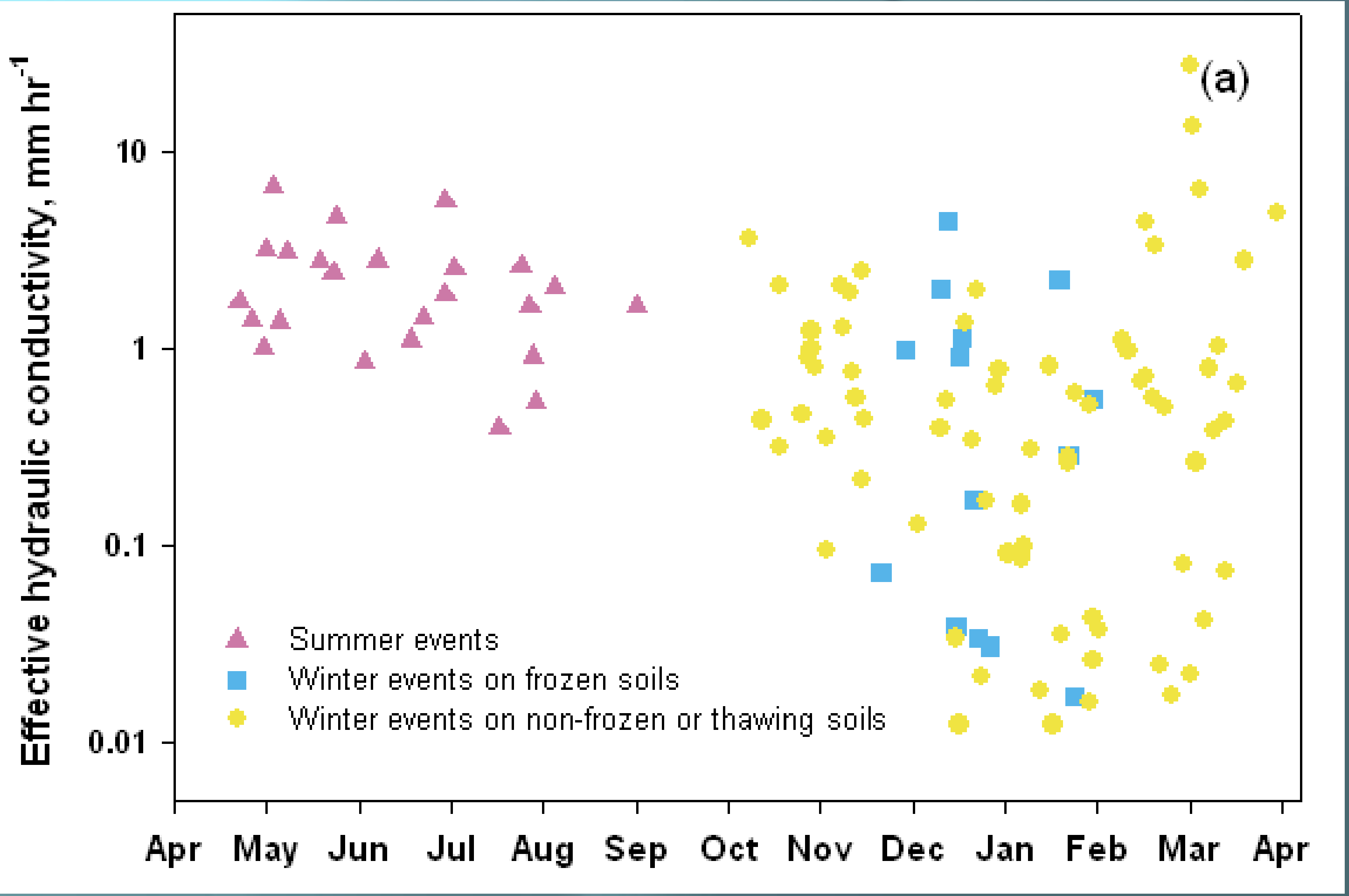
$$D_f = \frac{\beta V_f}{q}(T_c - G) \quad \ldots\ldots \quad G > T_c$$

x: distance downslope (m)
G, T_c: sediment load and transport capacity in a rill (kg s^{-1} m^{-1})
D_i, D_f, D_c: interrill sediment delivery rate, rill erosion or deposition rate and detachment capacity by rill flow (kg s^{-1} m^{-2})
K_r: rill erodibility parameter (s m^{-1})
τ, τ_c: flow shear stress on soil surface and critical shear stress (Pa)
V_f: effective fall velocity (m s^{-1})
q: discharge per unit width (m^2 s^{-1})
β: raindrop-induced turbulence coefficient

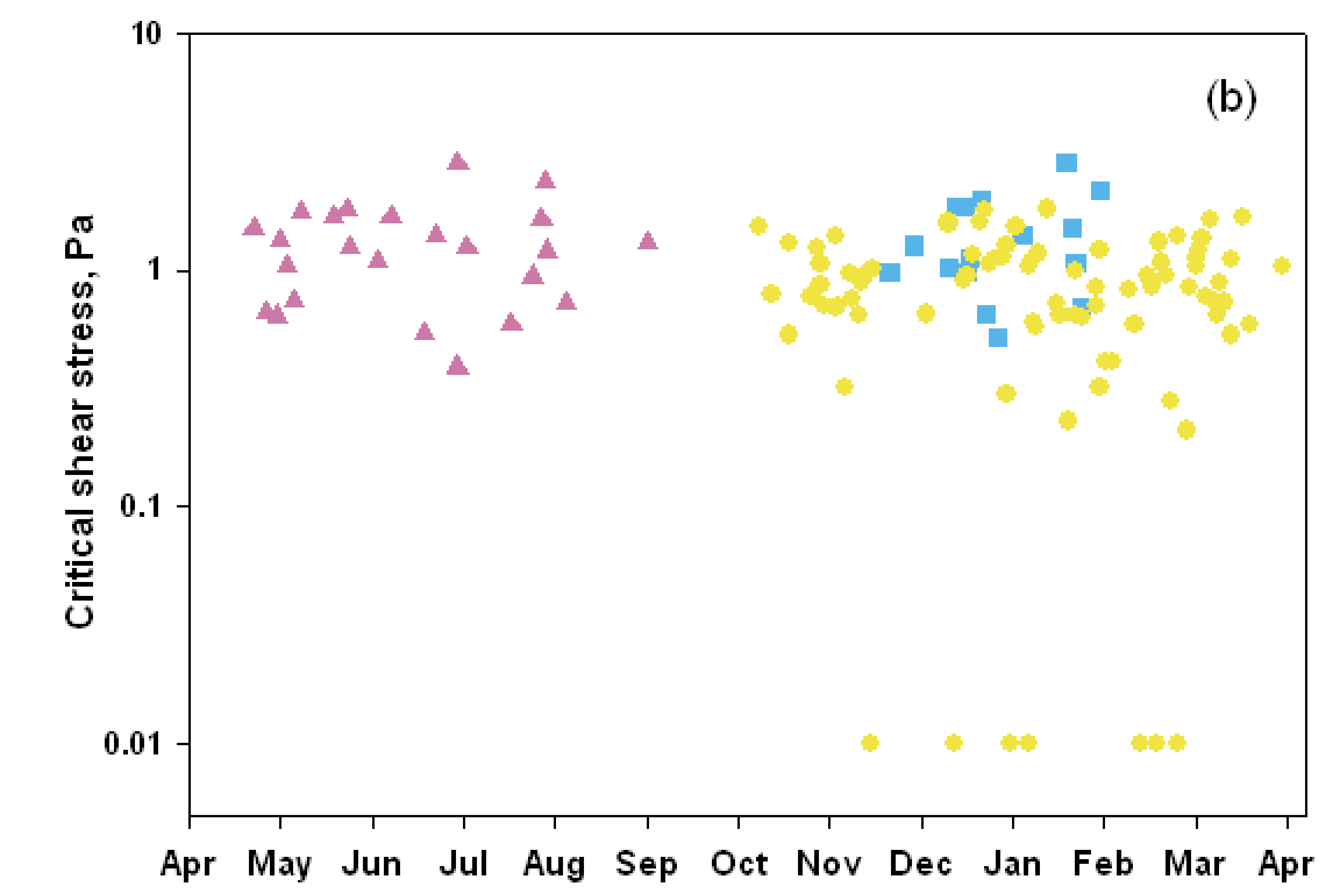
WEPP Inputs

- Break-point precipitation inputs were prepared from the observed rainfall and snowmelt data for each erosion event
- The remaining climatic inputs, including temperature, wind, humidity, and solar radiation, were from the NOAA Pullman 2 NW weather station
- Soil inputs for the Palouse silt loam were from the WEPP soil database with an initial soil saturation of 100%, and adjusted K_e, τ_c, and K_r
- Topographic inputs include field-measured slope dimensions, gradient, and aspect for plot #13

Fitted Effective Hydraulic Conductivity



Fitted Critical Shear Stress



Descriptive Statistics

Category	Sample size	Parameter	Runoff mm	Sediment yield t ha^{-1}	K_e mm hr^{-1}	τ_c Pa	K_r s m^{-1}
Summer events	24	Mean	3.2	3.0	2.3	1.27	0.017
		Std. Dev.	5.4	3.9	1.6	0.59	0.006
		Max	25.2	12.1	6.6	2.83	0.027
		Min	0.1	0.0	0.4	0.39	0.00017
		Skewness	3.4	1.3	1.5	0.80	−0.80
Winter events on frozen soils	16	Mean	9.8	1.2	0.8	1.37	0.016
		Std. Dev.	11.8	2.3	1.2	0.63	0.007
		Max	35.1	9.3	4.4	2.83	0.026
		Min	0.5	0.0	0.003	0.52	0.00017
		Skewness	1.4	3.1	2.1	0.81	−0.81
Winter events on non-frozen or thawing soils	86	Mean	7.1	13.4	1.2	0.85	0.022
		Std. Dev.	8.3	24.8	3.4	0.43	0.0048
		Max	36.5	154.8	27.2	1.80	0.031
		Min	0.1	0.0	0.00001	0.01	0.012
		Skewness	1.7	3.5	6.2	−0.09	0.081

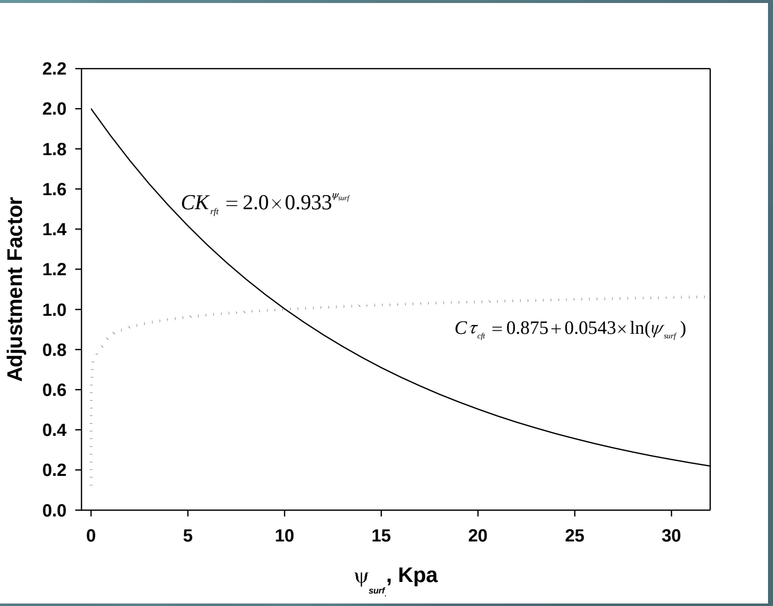
t-tests

- The values of K_e for winter events were 0.5 times those for summer events, significantly lower
- For winter frozen soils, τ_c was 1.2 times and K_r 0.8 times the values for summer soils, with no significant difference
- For winter non-frozen or thawing soils, τ_c was 0.4 times and K_r 1.5 times the values for summer soils, significantly more erodible

	t-tests	df	*t* -value	*P* (T≤t) one-tail	*t* critical one-tail
	Summer events vs. winter events on frozen soils	37	−3.35	0.0009	1.69
K_e	Summer events vs. winter events on non-frozen soils	84	−2.19	0.02	1.66
	Winter events on frozen vs. on non-frozen soils	66	0.87	0.19	1.67
	Summer events vs. winter events on frozen soils	31	0.51	0.31	1.70
τ_c	Summer events vs. winter events on non-frozen soils	30	−3.22	0.002	1.70
	Winter events on frozen vs. on non-frozen soils	18	−3.16	0.005	1.73

Current WEPP Adjustment Factors

- The adjustment factor for K_r in WEPP appears reasonable with a range of 0.2–2.0
- The maximum adjustment factor for τ_c is 1.1
- The adjustment factor for τ_c decreases rapidly once soil water content is near saturation (matric potential close to 0)
- Inadequate estimation of surface soil tension can cause problems



$C\tau_{cft}$: adjustment factor for freezing and thawing effects for critical shear stress
CK_{rft}: adjustment factor for rill erodibility
Ψ_{surf}: matric potential of surface soil (KPa)

Summary

- Field-observed runoff and soil erosion events on a continuous fallow runoff plot at PCFS were used to fit water erosion parameters (rill erodibility and critical shear stress) for each event using the WEPP model
- The observed erosion events were categorized into summer events, winter events on frozen soil, and winter events on non-frozen or thawing soils to examine the seasonal changes in hydraulic and erosion parameters

Summary con't

- For the study plot, it was found soils in winter were significantly less permeable than in summer; thawing or non-frozen soils in winter were significantly more erodible than in summer
- The WEPP adjustment for τ_c for soil freezing and thawing appears insufficient to adequately reflect seasonal changes in this parameter
- Future studies on soils in other cold regions are needed to develop systematic and sound approaches to adjusting the erodibility parameters in the WEPP model

Questions?

Thank You!