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Magnitude, Probability and Effect on Kinetic Energy of Winds Associated with Rains in Kansas[1]

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Introduction

Winds accompanying rains increase the rain's ability to cause soil detachment and clod disintegration (4). Winds cause horizontal, and greater total, velocity of raindrops, so they strike the soil surface with more force. Wind drag on the saturated surface of soil exposed to rain also contributes to the soil detachment process.[3]

This study investigated the magnitude and probability of occurrence of winds associated with rains at four locations in Kansas.

Procedure

Hourly rainfall and windspeed corresponding to each hour of rain were recorded from local climatic data at Dodge City, Topeka, Wichita, and Goodland, Kansas (Figure 1) for July 1956 to July 1964. November through February were not included because so little rain occurs then.

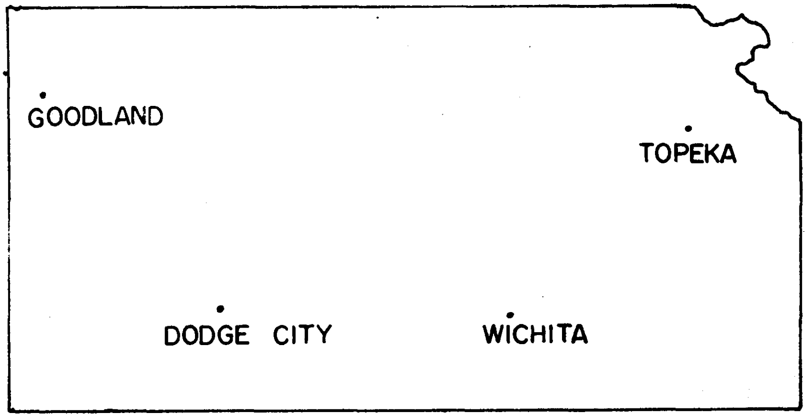

Figure 1. Outline map of Kansas showing study locations.

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[3] Disrud, Lowell A., and Roland K. Krauss. Examining the process of soil detachment from clods exposed to wind-driven simulated rainfall. Submitted to Transactions of ASAE for publication.

Elevation of the anemometer at Dodge City was changed during the study (Table 1). Because windspeed depends on elevation, it was necessary to adjust the Dodge City readings to a common elevation. Mean windspeed for each anemometer position at Dodge City was determined, as were mean windspeeds for the two time periods so it was assumed that differences at Dodge City resulted from different anemometer heights. The Dodge City data for July 1956 to April 1961 were adjusted to the new anemometer height by subtracting the difference in means for each period from each observation (5).

Various statistical procedures were used to simplify determining the magnitude of winds accompanying rains. Normality of distribution of windspeeds was examined by plotting the data on probability paper. Correlation between rainfall intensity and windspeed was determined. The relationship between all hourly data and the data for the first hour of each storm was determined in an attempt to reduce the work involved in assembling the data. Probabilities of windspeeds accompanying rains were determined.

Results and Discussion

To use standard statistical methods in analyzing data, the data must approximate a normal distribution (3). Because logarithmic transformation was required to make the data approximate normal distribution, all statistical operations were performed on the $\log_{10}$ of windspeed.

Table 2 summarized tests used to determine differences in means and variances between hourly data and first hour data. The first hour data are those for the first hour during which at least. .10-inch of rain fell for each storm. The probabilities listed are the probabilities of finding a larger value for the test parameter when the hypothesis being tested is true. In all tests the probabilities were high enough to conclude that the means or variances between the data for every hour and the data for only the first hour of each storm were not significantly different; therefore, the two sets of data represent the same statistical population. That being so, data for the first hour of each storm can be used to determine windspeed

Table 1. Anemometer elevations, July 1956 to July 1964.

Location	Time period	Height in feet
Dodge City	7-56 to 4-61	58
Dodge City	5-61 to 7-64	20
Topeka	7-56 to 7-64	20
Wichita	7-56 to 7-64	32
Goodland	7-56 to 7-64	31

probabilities, and thus greatly reduce time and labor required to tabulate the total data from weather records.

Table 3 summarized the correlation between windspeeds and rainfall intensity for each location. The correlations were statistically significant at two locations but they were low enough that it was assumed that windspeed accompanying rains could be predicted without regard to rainfall intensity.

It can be seen from Figure 2 that windspeeds tend to be highest during March, April and May. Points on this graph represent the average of first hour windspeeds for each month of the 8-year period. Because of seasonal variations, prediction based on all data for the year would underestimate winds in March, April and May. Deviations from the yearly geometric mean for each month are shown in Table 4.

Figures 3, 4, 5, and 6 show the probabilities of wind of various speeds accompanying rains at each location. The probability curves for Topeka, Wichita and Goodland are similar, but the one for Dodge City differs somewhat. Even with probability curves similar, windspeed corresponding to a given probability may differ by locations with seasonal variations. Monthly deviations from Table 3 should be added to any windspeed determined from Figures 3, 4, 5 and 6 to determine wind probability.

Table 2. Summary of tests for difference in means and variances between hourly windspeed data and first hour windspeed data.

Location	Hypothesis tested	Test parameter	Probability
Dodge City	Hourly mean = first hour mean	T = .86	.04
Dodge City	Hourly variance = first hour variance	F = 1.32	.05
Topeka	Hourly mean = first hour mean	T = .71	.40
Topeka	Hourly variance = first hour variance	F = 1.19	.25
Goodland	Hourly mean = first hour mean	T = .45	.50
Goodland	Hourly variance = first hour variance	F = 1.08	.40
Wichita	Hourly mean = first hour mean	T = 1.63	.15
Wichita	Hourly variance = first hour variance	F = 1.06	.40

Table 3. Correlation between first hour rainfa'l intensity and $\log_{10}$ windspeed.

Location	Correlatioin r	Number of observations	Significance
Dodge City	.1109	204	..
Topeka	.1815	300	*
Wichita	.1233	290	†
Goodland	.1450	153	..

* Significant at 0.01 level.
† Significant at 0.05 level.

Example: At Dodge City in April, the windspeed is expected to be 21.7 m.p.h. or greater 20 percent of the time (17 m.p.h. from Figure 3 plus 4.79 m.p.h. from Table 4). Windspeeds for the same conditions at Topeka, Wichita, and Goodland are 21.7, 21.1 and 19.5, respectively.

Amount of soil eroded by rain is closely related to the kinetic energy of the rain (6.). Velocity of a raindrop falling in wind is the resultant of the terminal vertical velocity of the drop in still air and the horizontal windspeed (2). That permits one to estimate the expected change in rainfall kinetic energy caused by wind.

The relationship between wind velocity and elevation depends on ground surface roughness, terrain, and atmospheric stability. The follow-

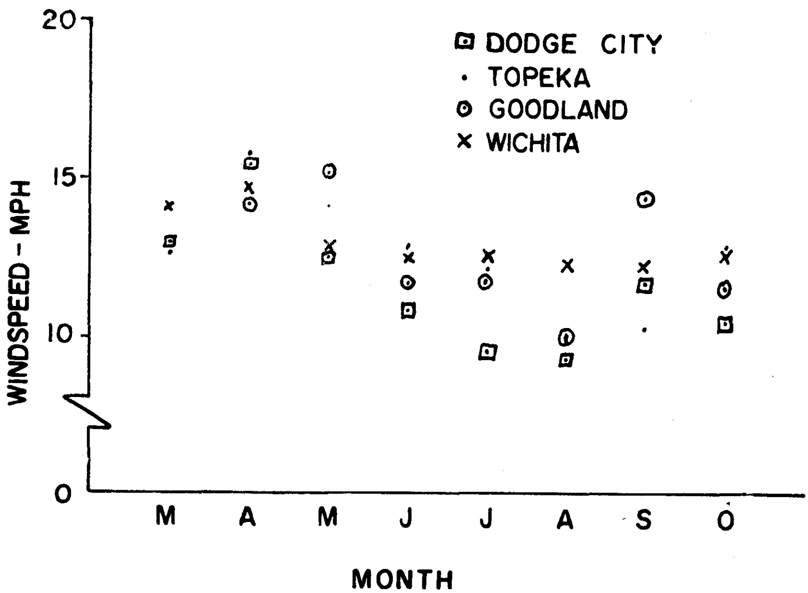

Figure 2. Monthly variation in windspeeds associated with rains.

Table 4. Windspeed (m.p.h.) deviation of monthly geometric means from overall geometric mean for each location.

Location	March	April	May	June	July	Aug.	Sept.	Oct.
Dodge City	2.10	4.70	1.81	–.07	–1.24	–1.45	.96	–.32
Topeka	–.08	3.18	1.46	•.22	–.52	–2.66	–2.37	.22
Wichita	.94	1.61	–.30	–.62	–.59	–.88	–.88	–.62
Goodland	.. ....	1.54	2.55	–.84	–.84	–2.59	1.87	–1.11

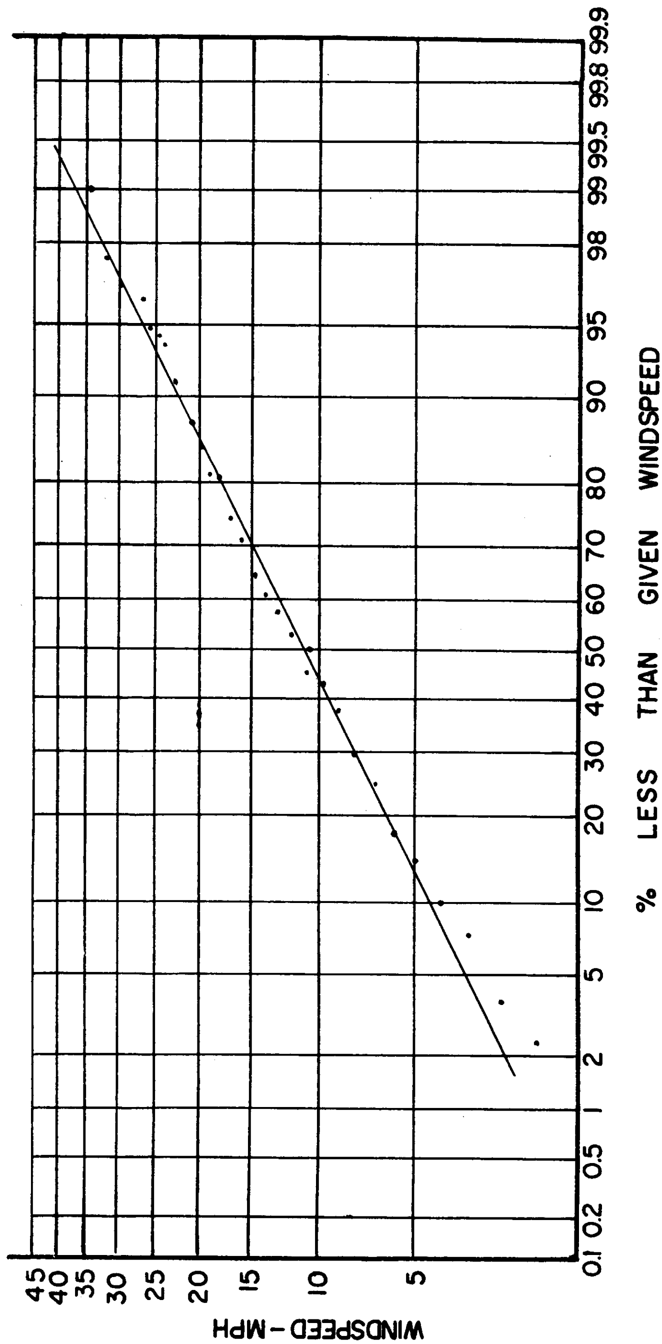

Figure 3. Probabilities of wind of various speeds accompanying rains at Dodge City, Kansas.

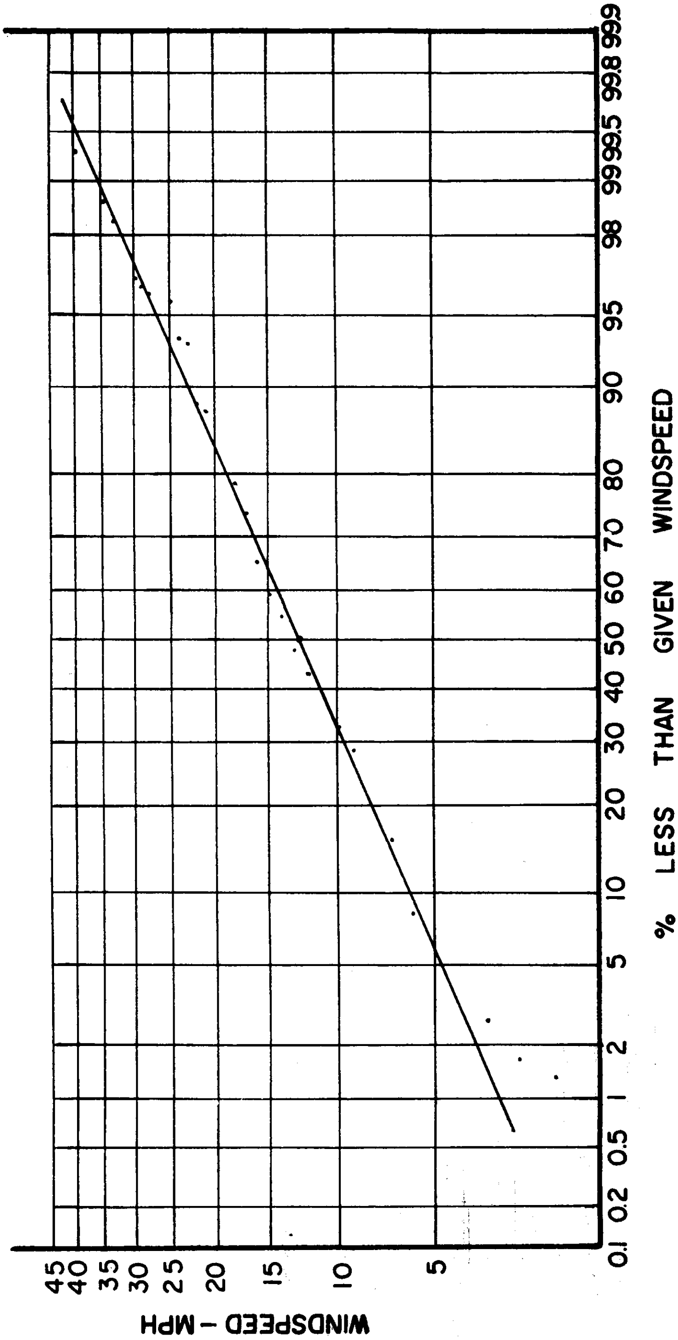

Figure 4. Probabilities of wind of various speeds accompanying rains at Topeka, Kansas.

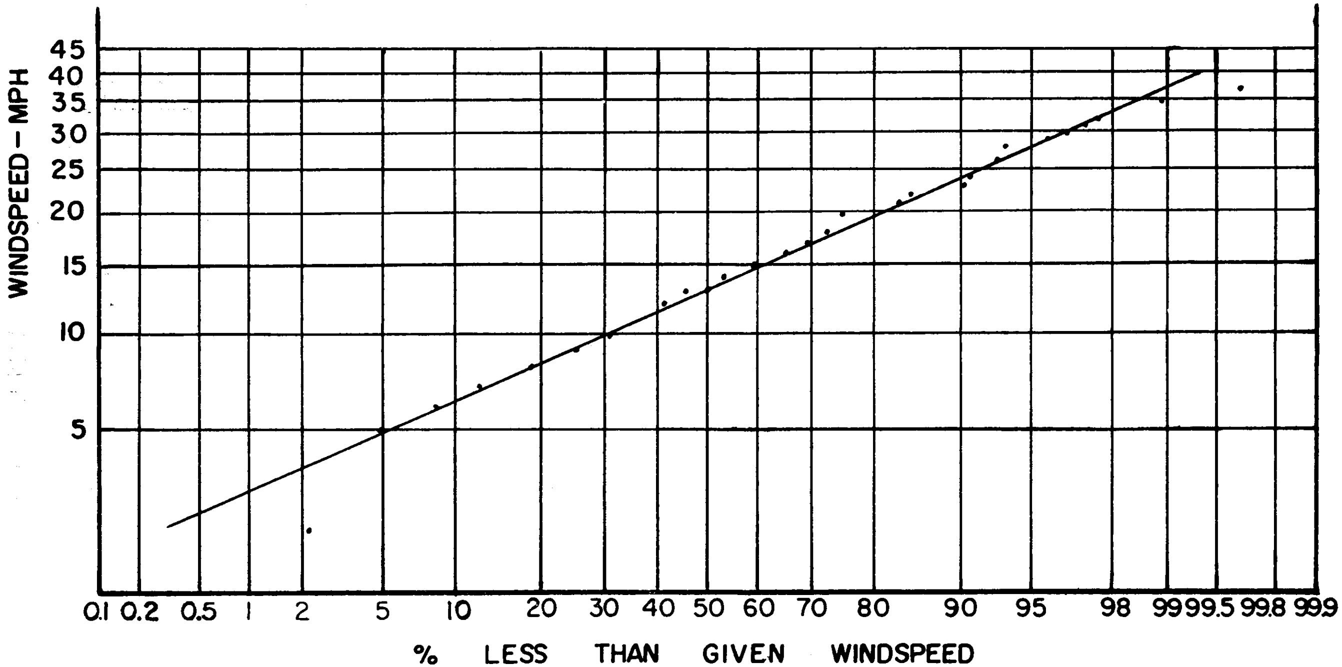

Figure 5. Probabilities of wind of various speeds accompanying rains at Wichita, Kansas.

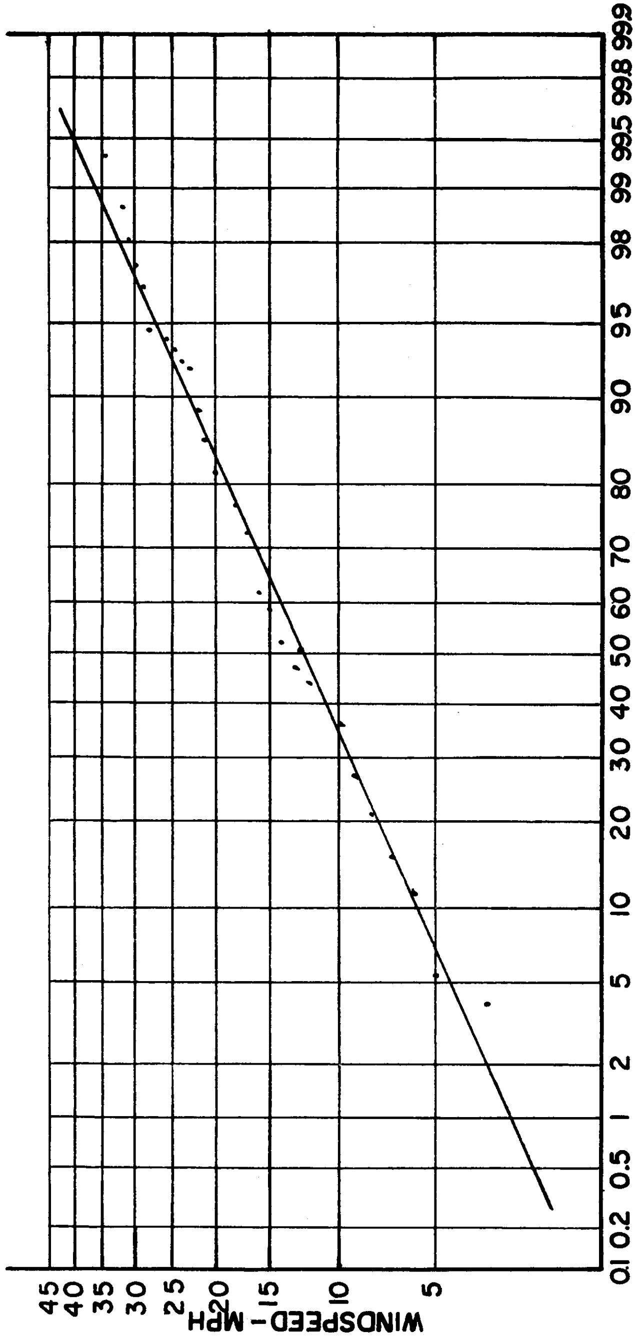

Figure 6. Probability of wind of various speeds accompanying rains at Goodland, Kansas.

ing equation is commonly used to describe the velocity-height relationship over level terrain in the fully turbulent adiabatic boundary layer (1):

$$U_z = 5.75\, U_* \log \left(\frac{Z - d}{Z_0}\right)$$

where U_* = drag velocity (m.p.h.)

U_z = mean velocity at height Z (m.p.h.)

Z = elevation above surface (in.)

d = effective roughness height (in.)

Z_0 = roughness parameter (in.)

The 80 percent windspeed for Dodge City in April is approximately 22 m.p.h. at a height of 20 feet (from example shown, using data from Figure 3 and Tale 4). That means that 80 percent of winds accompanying rains were less than that windspeed and 20 percent were more. Using d = .79 inch and Z_0 = .39 inch, the mean windspeed at 5 feet is approximately 17 m.p.h. If raindrops that fall 30 feet per second (20 m.p.h.) in still air have a horizontal velocity equal to the wind velocity at 5 feet when they strike the ground, their kinetic energy is increased 72 percent by the wind. The relationship between horizontal rain drop velocity and the wind velocity profile is not yet known. Wind velocity at 5 feet was used only to estimate the relative importance of wind in increasing raindrop kinetic energies.

Conclusions

Wind accompanying rains in Kansas are sufficient to significantly affect the rain's ability to cause soil erosion. At Dodge City in April, 20 percent of winds with rains have speeds of 22 m.p.h. or greater. Corresponding windspeeds at the other locations ranged from 19.5 m.p.h. to 22 m.p.h. A wind of 22 m.p.h. at an elevation of 20 feet may increase the rain's kinetic energy by 72 percent at the soil's surface.

The windspeed data were not normally distributed but a logarithmic transformation of the data was nearly normal. Windspeed and rain intensity were not highly correlated, so rain intensity does not need to be specified when predicting windspeeds that accompany rains. The first hour of each rainstorm of .10 inch or more is representative of the storm.

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