Dust Deposition in Relation to Site, Season, and Climatic Variables[1]

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ABSTRACT

Mean monthly dust deposition into standard traps for 14–37 mo at 14 locally nondusty sites east of the Rocky Mountains ranged from 17–459 kg/ha (15–410 lb/acre). Analyses of variance for 13 sites over 27 mo showed significant differences in dust rates, pH, oxidizable matter, and percent clay for sites and for months.

Some late fall and winter months showed significantly lower rates than late spring and summer. The silt plus sand fraction tended to be lower and the percentages of oxidizables were higher for low deposition rates and eastern sites. pH decreased, generally, from west to east. Grass phytoliths were prominent. Illite and kaolinite were dominant over montmorillonite in clay fractions.

Correlation analyses showed positive relations between dust deposition rates and some power of average monthly wind velocity either near the stations or for western Kansas winds. Rainfall parameters tended to correlate positively with dust catch at most stations and at all stations combined, suggesting that considerable sediment is carried down by rainfall. Deposition rates were positively correlated among sites.

Multiple regression equations for predicting monthly dust deposition, using wind, rainfall, and season parameters, seem useful at several locations.

Additional Key Words for Indexing: **dust and weather relationships, dust variability, dust sampling network, and regression.**

Standardized continuous trapping of dust was begun in 1963 at widely spaced locations east of the Rocky Mountains. The first trap was established May 20, 1963, at Manhattan, Kans. (7), and others were installed later at 14 more locations. Enough data now have been collected to establish some meaningful statistical relationships. Results through December 1966 are included here. Later results through June 1967 appear consistent with the conclusions presented.

The study was conducted primarily to obtain information on soil renewal rates. That involved determining quantities and characteristics of solids deposited on soil surfaces over extensive regions and establishing interrelations among locations.

Also considered were seasonal, climatic, or other measurable variables that might help identify dust sources and courses of transport and enable useful predictions for areas not sampled. Information about dust sources, transport, and deposition also contributes to better understanding of wind erosion, erodibility of particular soils and minerals, and likely distribution of pollutants.

Details of dust traps used were given earlier (7), and so are only briefly described here. Selection of the standard trap was arbitrary. It may catch more or less material than some other type of trap. However, it provides a reasonable basis for comparisons among sites and over time; and rates should correlate with soil change or deposition determined by other means.

The 15 locations with gages are shown in Fig. 1; 17 traps were used, two each at Coshocton, Ohio, and Big Spring, Tex. Dust traps at St. John, Kans., and Big Spring, Tex., were established later than others so data from these are omitted from most of the calculations.

Dust traps were exposed to normal climatic conditions similar to standard rain gages. An additional requirement was that the sites must be nondusty locations protected for a minimum of 100 m by surrounding ground cover, thus preventing observable soil movement by wind.

EXPERIMENTAL PROCEDURE

Collection and Laboratory Procedure

The dust trap used consisted of the overflow cylinder of the ESSA-Weather Bureau standard 203-mm (8-in) nonrecording rain gage and two screens mounted in the top of the cylinder (bottom screen had 1-mm openings; top had 6.35-mm openings). Water or antifreeze was maintained in the gage to trap the dust. After the suspension from each trap was removed at the end of each calendar month, the samples were forwarded to the Agricultural Research Service Wind Erosion Laboratory at Kansas State Univ. for processing. The quantity of dust removed from each gage was usually 0.05–1.0 g.

Principles of processing for particle sizing and mineral study followed Kunze and Rich (4) or Jackson (3) with adaptations necessitated by size or sample peculiarities. Acid treatment was avoided to preserve carbonates and cemented aggregates. Air-dry colors were determined by standard Munsel charts and pH was obtained with a glass electrode meter. Each dust sample was treated repeatedly with a 30% solution of hydrogen per-

Fig. 1—Locations of dust gages used in the study.

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Table 1—Oxidized dust weight, silt plus sand percentage, dust pH, and percent loss by oxidation for 27 mo

Location	Mean monthly oxidized dust	Significance grouping* (F = 6.7)	Mean monthly silt plus sand percentage	Significance grouping* (F = 13.0)	Mean monthly dust pH†	Significance grouping* (F = 25.7)	Mean monthly loss by oxidation	Significance grouping* (F = 14.0)
	kg/ha						%	
Tribune‡			79.2	4	8.0	4	2.9	8
North Platte	75.7	4	76.0	4 5	7.1	5 6	9.6	7 8
Sidney	69.7	4	64.9	6 7	7.9	4	11.4	6 7
Oxford	61.6	4	62.2	7 8	6.3	7 8	24.6	4
Hays	56.8	4 5	69.0	5 6	7.2	5 6	7.6	7 8
Manhattan	50.3	4 5 6	63.0	7 8	7.1	5 6	11.5	6 7
Marcellus	49.2	4 5 6	61.6	7 8	6.3	7 8	25.5	4
McCredie	47.5	4 5 6	61.7	7 8	6.7	6 7	10.8	6 7
Marlboro	28.4	5 6	56.9	7 8 9	6.4	7 8	18.5	5
Riesel	23.5	6	62.4	7 8	7.6	4 5	10.2	6 7
Water Valley	21.6	6	52.7	9	7.7	4	12.1	6 7
Coshocton N	17.2	6	55.0	8 9	5.9	8	18.2	5
Coshocton S	16.8	6	57.8	7 8 9	6.1	8	17.1	5 6

* 5% level by the sequential method of testing as described by Snedecor (8) and credited to Hartley. For a particular significance grouping, identical numbers identify the group within which individuals are not significantly different.
† Although an average pH may be invalid technically, it tends to show differences, especially when the range of averaged values is relatively small.
‡ Tribune, Kansas, data not included in the analyses of mean monthly oxidized dust.

oxide to destroy organic material, including recognizable plant or insect remains. Samples above 0.05 g were dispersed by soaking overnight with Calgon added and stirring at high speed for 15 min (Use of this product does not imply endorsement by USDA or its superiority to other competing products). After centrifuge separation, clay was flocculated with NaCl (in early samples with HCl [7]) then saturated with Mg by washing with $MgCl_2$.

Oriented clay slides, formed by evaporation from an approximately 1% suspension, were monitored from 62 to 1.5 degrees 2θ at room temperature with a Norelco diffractometer using nickel-filtered copper radiation. Then after ethylene glycol treatment, each slide was monitored a second time from 15 to 1.5 degrees. When sufficient clay was available, an additional slide was X-rayed from 15 to 1.5 degrees after being heated 0.5 hour at 450 and 600C.

Subsamples of silt and sand were mounted permanently in Canada balsam for optical study. Data on median and maximum particle sizes are presented here.

Climatic Variables

Standard ESSA-Weather Bureau measurements used to help explain deposition rates included: Mean monthly wind velocity at 6.1 m (20 feet) at the nearest official meteorological station; at the same height, the number of 3-hour-interval recordings of wind velocity $\geq$ 5.7 m/sec and $\geq$ 11.3 m/sec; total monthly rainfall; number of days with rainfall $\geq$ 0.254 mm (0.01 in), $\geq$ 2.54 mm (0.10 in), and $\geq$ 6.35 mm (0.25 in); number of 3-hour-interval occurrences of dust or blowing dust; and number of dusty days. In addition, some detailed low-level wind measurements, air temperatures, and recorded storm tracks were considered.

RESULTS

Dust Deposition Rates

Table 1 contains mean monthly oxidized dust data for 12 widely spaced sites for 27 mo ending July 1, 1966. Deposition at Tribune, Kans. (not included in Table 1), averaged 459.4 kg/ha (410.2 lb/acre) per month.

Because Tribune was believed to be in the principal source region for dust (7), it seemed logical to omit data for that location from the analyses of mean monthly dust deposition. With Tribune data included, differences detected between sites were not significant except dust deposition at Tribune was statistically different from each other site. With Tribune data omitted, dust deposition rates at other locations were significantly different. Collective mean monthly dust deposition rate for the sites, except Tribune, listed in Table 1 ranged from 13.2 kg/ha (11.8 lb/acre) in November 1965 to 83.7 kg/ha (74.7 lb/acre) in June 1966. The collective means for several late spring or summer months in 1964 and 1966 were significantly higher than monthly means for several winter months during 1964 to 1966.

Properties of Dust

Silt and Sand—Table 1 shows significant site mean differences for silt plus sand after peroxide treatment of dust samples. Material not measured as silt or sand included all crystalline and amorphous solids of settling velocity less than that of spheres 2 μmean diameter and 2.65 sp gr as well as material dissolved during processing. More solid matter was lost by solution during processing than anticipated. Clay percentages, therefore, are less than indicated by silt plus sand unless all solution losses were from clay size particles.

Collective monthly means of percent silt plus sand for the 13 sites listed in Table 1 ranged from 51.9 in July 1965 to 73.5 in June 1965. Some means were significantly different among months.

pH—Mean monthly pH ranged from 8.0 at Tribune, Kans., on the west to 5.9 at Coshocton, Ohio, well to the east (Table 1). Other sites as far west as McCredie, Mo., showed average pH below 7.0.

The collective means of monthly pH for all sites ranged from 6.1 in April 1965 to 7.7 in August 1964 with several significant differences among months.

Some pH measurements of soil samples may lack normal precision because samples were small and some early determinations were colorimetric (7). Some error also resulted from the trapping liquid not always being drawn off and discarded, i.e., in a few cases it was evaporated to dryness with the dust.

Oxidation—Partially decomposed plant and insect remains, evident in some samples, influenced oxidation losses. Also, carbonates not being removed may have influenced the losses.

Table 1 shows significant mean differences among sites.

Collective monthly means of percent weight loss by oxidation for the 13 sites ranged from 3.3 in March 1965 to

Table 2—Mineralogy of clay fraction ($< 2\mu$) of monthly dust deposition at indicated locations, 1963–65*

Location	Montmorillonite A	Montmorillonite B	Illite A	Illite B	Kaolinite A	Kaolinite B	Chlorite A	Chlorite B	Quartz A	Quartz B	Feldspars A	Feldspars B	Other A	Other B	Total crystal rating
Sidney	7/10	0.80	9/10	1.80	9/10	1.50	7/10	0.70	9/10	1.00	5/10	0.50	6/10	0.80	7.1
Coshocton S	7/10	0.70	10/10	1.80	9/10	2.20	6/10	0.60	6/10	0.70	6/10	0.60	3/10	0.40	7.0
Riesel	9/15	1.00	15/15	1.53	13/15	1.59	7/15	0.47	10/15	0.87	8/15	0.67	5/15	0.47	6.6
North Platte	10/14	1.07	14/14	1.79	12/14	1.42	4/14	0.43	9/14	0.79	7/14	0.50	7/14	0.50	6.5
Tribune	13/17	1.35	16/17	1.59	16/17	1.27	7/17	0.41	10/17	0.59	10/17	0.59	8/17	0.59	6.4
Manhattan	7/25	0.32	25/25	1.64	24/25	2.76	7/25	0.28	13/25	0.52	9/25	0.36	10/25	0.44	6.3
Hays	14/23	0.74	21/23	2.04	21/23	1.74	6/23	0.26	11/23	0.52	11/23	0.52	6/23	0.30	6.1
Coshocton N	3/12	0.33	11/12	1.58	12/12	2.00	7/12	0.67	6/12	0.50	6/12	0.50	5/12	0.42	6.0
Marlboro	7/14	0.50	13/14	1.57	12/14	1.57	5/14	0.50	5/14	0.36	6/14	0.50	6/14	0.57	5.6
Water Valley	7/13	0.54	12/13	1.38	13/13	1.54	4/13	0.31	7/13	0.54	5/13	0.38	6/13	0.70	5.4
Marcellus	5/14	0.35	14/14	1.30	13/14	0.93	9/14	0.71	9/14	0.64	6/14	0.43	10/14	0.88	5.2
Akron	3/5	1.00	4/5	1.20	4/5	1.00	3/5	0.60	2/5	0.40	2/5	0.40	2/5	0.40	5.0
McCredie	6/12	0.50	11/12	1.42	10/12	1.17	0/12	0.0	3/12	0.25	4/12	0.33	6/12	0.75	4.4
Oxford	3/15	0.20	10/15	0.93	9/15	0.93	4/15	0.27	6/15	0.47	3/15	0.40	4/15	0.40	3.6
Average	8/14	0.67	13/14	1.54	13/14	1.54	5/14	0.44	8/14	0.58	6/14	0.48	6/14	0.54	5.8

* August 1963 through 1965. Months represented are not identical because of different starting dates and some samples too small for determination.

A = Ratio of: $\frac{\text{Number of months mineral was present}}{\text{Number of months included in study}}$.

B = Mineral rating average where relative concentrations are indicated by a scale from 1 to 5 with 1 representing an estimated 10% or less, 2 representing 10 - 25%, 3 from 25 - 50%, 4 from 50 - 75%, and 5 representing 75% or more.

28.9 in August 1964. Several significant differences among months were indicated.

Clay Mineralogy—Oriented slides for X-ray diffraction were thinner than intended because of excessive solution loss during processing. All slides were covered with readily observable films, but clay weights per slide varied considerably. All were less than 25 mg.

Table 2 shows frequency of occurrence and relative ratings of several minerals in clay fractions.

Climatic Influences

Table 3 shows correlation coefficients for dust deposition versus powers of mean monthly wind velocity either near the site or at two locations in western Kansas. First, third, and fourth powers are shown. R values for second powers in all cases were intermediate between first and third power results. Fifth powers tested were essentially equal to fourth powers or gave lower R values. For all sites, 132 observations, the R values for the fifth power was 0.392.

Generally the number of 3-hour-interval observations of wind $\geq$ 5.7 m/sec or $\geq$ 11.3 m/sec failed to correlate

Table 3—Correlation coefficients for monthly dust deposition versus mean monthly wind velocity at 6.1 m (20 ft)

Location	No. of obs.	Nearest standard station WV	Nearest standard station WV^3	Nearest standard station WV^4	Dodge City, Kansas WV^3	Dodge City, Kansas WV^4	Dodge City, Kansas Previous mo WV^3	Goodland, Kansas WV^3	Goodland, Kansas WV^4	Goodland, Kansas Previous mo WV^3
		Correlation coefficients R*								
Manhattan	43	0.352	0.398	0.415	0.598	0.613	0.334	0.462	0.451	0.559
Hays	38	0.512	0.531	0.538	0.531	0.538	0.210	0.523	0.517	0.334
Tribune	33	0.620	0.672	0.696	0.672	0.696	0.277	0.541	0.554	0.609
McCredie	33	0.106	0.082	0.070	0.056	0.066	0.096	0.178	0.175	0.287
Akron	20	0.478	0.514	0.531	0.335	0.325	0.112	0.619	0.634	0.643
Coshocton N	32	-0.069	-0.111	-0.130	0.198	0.192	0.137	0.306	0.314	0.318
Coshocton S	32	-0.134	-0.176	-0.194	0.190	0.196	-0.009	0.289	0.301	0.337
Marcellus	34	-0.382	-0.363	-0.351	0.107	0.109	0.222	0.111	0.097	0.356
Marlboro	33	0.327	0.297	0.272	-0.025	-0.022	-0.128	-0.005	0.0	-0.252
North Platte	32	0.477	0.439	0.414	0.537	0.537	0.441	0.548	0.539	0.622
Oxford	31	-0.017	-0.068	-0.089	-0.054	-0.054	0.289	0.040	0.033	0.105
Riesel	34	0.337	0.329	0.317	0.385	0.396	0.140	0.532	0.554	0.113
Sidney	31	-0.002	-0.020	-0.025	0.255	0.244	0.177	0.331	0.325	0.325
Water Valley	33	0.350	0.335	0.320	0.233	0.236	0.508	0.504	0.515	0.347
All†	132	0.369	0.392	0.395						
All†	203	0.289	0.356							

* Significance:

	Number of observations 20	43	132
5%	.444	.300	.170
1%	.561	.390	.225

† All sites, 132 observations, include samples through 1965 with mineral identification complete; 203 observations include all through 1965 with clays identified.

closer with dust deposition than did mean monthly velocity alone. Exceptions were McCredie, R = 0.248 for winds $\geq$ 11.3 m/sec; North Platte, R = 0.571 for winds $\geq$ 5.7 m/sec; and Riesel, R = 0.414 for winds $\geq$ 5.7 m/sec.

More R values were positive for Kansas winds than for winds near other sites. Only at Marlboro, N.J., did dust deposition fail to correlate positively with wind at Goodland, Kans.

Correlation coefficients between total monthly rainfall and numbers of rainy days versus dust deposition at the several sites are given in Table 4. Limited testing of the second and the one-half powers of rainfall indicated no useful improvements over first power relations.

At most weather stations the number of observations of visible dust was too low for meaningful correlations. Dust occurrences were greatest at North Platte, Goodland, and Dodge City, but even there no dust was visible most months.

Correlations were run for monthly dust depositions at 14 sites versus depositions at Manhattan, North Platte, and Riesel, and versus four "season indices" (Table 5). Sites with shorter records determined the number of monthly comparisons in each calculated correlation.

"Season index" was defined as the average dust deposition at a site for a particular month for the period of dust

Table 4—Correlations between monthly dust deposition and rainfall near each dust trap*

Location	No. of obs.	mm of rainfall	Number of rains >6.35 mm	Number of rains >2.54 mm	Number of rains >0.254 mm
		R			
Manhattan	43	0.302	0.419	0.597	0.513
Hays	38	0.241	0.226	0.204	0.307
Tribune	33	0.474	0.438	0.362	0.165
McCredie	33	0.469	0.417	0.349	0.323
Akron	20	0.895	0.736	0.626	0.408
Coshocton N	32	-0.211	-0.183	-0.131	0.079
Coshocton S	32	-0.268	-0.210	-0.158	0.023
Marcellus	34	-0.129	-0.228	-0.163	-0.419
Marlboro	33	0.121	0.270	0.089	0.081
North Platte	32	0.473	0.469	0.376	0.249
Oxford	31	0.015	0.243	0.062	0.155
Riesel	34	0.281	0.213	0.134	0.274
Sidney	31	0.180	0.173	0.051	0.157
Water Valley	33	0.109	0.071	0.079	0.074
All	132	0.078	0.050	0.041	
All	203	0.130	0.124	0.081	0.020

* Significance:

	Number of observations 20	43	203
5%	.444	.300	.138
1%	.561	.390	.181

Table 5—Simple correlation coefficients* for monthly dust deposition at each of 14 sites versus monthly dust deposition at Manhattan, Kans., North Platte, Nebr., and Riesel, Tex., and versus four "season indices"

		Sites and indexes correlated						
		Monthly dust deposition			Season index			
Location	No. of obs.	Manhattan	North Platte	Riesel	General	Manhattan	Tribune	Marcellus
		R						
Manhattan	43	1.000			0.458	0.734	0.577	0.527
Hays	38	0.614	0.347	0.278	0.580	0.684	0.580	0.411
Tribune	33	0.621	0.384	0.353	0.420	0.499	0.624	0.269
McCredie	33	0.459	0.129	0.048	0.301	0.370	0.279	0.118
Akron	20	0.585	0.603	0.087	0.110	0.568	0.514	0.663
Coshocton N	32	0.400	0.366	0.155	0.144	0.316	0.342	0.231
Coshocton S	32	0.497	0.264	0.175	0.206	0.363	0.380	0.198
Marcellus	34	0.538	0.744	-0.220	-0.056	0.581	0.335	0.840
Marlboro	33	-0.190	0.104	0.251	-0.103	-0.255	-0.110	-0.135
North Platte	32	0.725	1.000	-0.105	0.067	0.655	0.525	0.837
Oxford	31	0.239	0.289	-0.175	0.230	0.453	0.517	0.296
Riesel	34	0.193	-0.079	1.000	0.523	0.143	0.275	-0.278
Sidney	31	0.195	0.483	-0.064	-0.088	0.102	0.021	0.235
Water Valley	33	0.251	-0.096	0.418	0.288	0.226	0.246	-0.081

* Significance: Number of observations

	20	32	43
5%	.444	.349	.300
1%	.561	.449	.390

records. Thus each location had a season index value for each month of the year. To obtain "general season indices" these values were arbitrarily assigned to the 12 calendar months: January, 1.0; February, 1.2; March, 2.0; April, 2.0; May, 1.6; June, 1.2; July, 1.4; August, 1.4; September, 1.3; October, 1.3; November, 1.2; and December, 1.0.

A multiple regression equation for predicting dust deposition was developed for 13 of the sites. Equations that appeared to be the most useful for predicting dust deposition rates are presented below. These are of the standard form: $Y = K_1 + K_2X_1 + \ldots + K_{n+1}X_n$. "Y" is in kg/ha.

Tribune, Kans. (33 observations). $R = 0.892$, $F = 37.8$

$$Y = -493 + 192\,X_1 + 8.0\,X_2 + 0.2875\,X_3^4$$

X_1 = Dodge City, number of 3-hour-interval occurrences of dust

X_2 = Tribune, monthly rainfall in mm

X_3 = Dodge City, average wind velocity in m/sec

Akron, Colo. (21 observations). $R = 0.888$, $F = 21.1$

$$Y = 79.8 + 2.04\,X_1 + 52.6\,X_2 - 0.834\,X_3^3$$

X_1 = Akron, monthly rainfall in mm

X_2 = Goodland, number of dusty days

X_3 = Goodland, average wind velocity in m/sec

Manhattan, Kans. (43 observations). $R = 0.767$, $F = 18.5$

$$Y = -15.4 + 0.074\,X_1^3 + 0.021\,X_2^4 + 4.5\,X_3$$

X_1 = Goodland, previous month average wind velocity in m/sec

X_2 = Dodge City, current month average wind velocity in m/sec

X_3 = Number of days with rainfall $\geq$ 2.54 mm (0.10 in)

Hays, Kans. (38 observations). $R = 0.769$, $F = 12.0$

$$Y = -1.5 + 53.1\,X_1 - 0.15\,X_2^3 + 0.021\,X_3^4 + 0.58\,X_4$$

X_1 = Manhattan, season index

X_2 = Goodland, previous month average wind velocity in m/sec

X_3 = Dodge City, current month average wind velocity in m/sec

X_4 = Number of days with rainfall $\geq$ 0.254 mm (0.01 in)

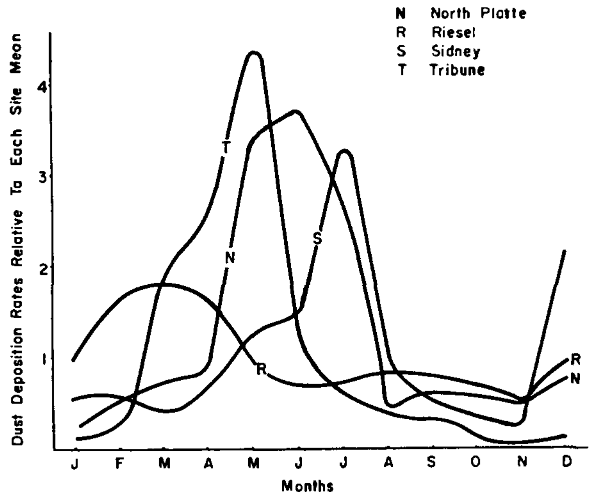


Fig. 2—Relative mean monthly dust deposition rates for four sites in different latitudes.

DISCUSSION

Twenty-seven months were ample to show distinct differences in dust deposition rates among sites and among months. Using monthly rates as replicates, some sites remained undifferentiated even though the site means differed by as much as 33.6 kg/ha (30 lb/acre). That is reasonable because seasonal or other variables caused higher rates first at one site then at another unless site differences were large.

Although sites differed in latitude, there was a marked tendency toward higher deposition rates in late spring and summer than in fall and winter even with Tribune, Kans. omitted. The tendency would be more pronounced with Tribune included because its highest rates were in April, May, and June. With references to collective monthly means for 12 of the sites, the 8 months with highest dust deposition were April, May, and July 1964; April, May, and June 1965; and May and June 1966. The 9 months with lowest deposition were in fall or winter.

Seasonal variability of dust deposition at four sites is illustrated by Fig. 2. Other sites showed mean peak rates as follows: Water Valley, February and August; McCredie, April; Manhattan, May; Coshocton, May; Akron, May; Marcellus, June; Hays, March, May, and August; Oxford, August; and Marlboro, March, July, and December.

Peaks in February and March in Texas, in April or May at most of the mid-latitude stations, in June at North Platte and Marcellus, and in July at Sidney, Mont., suggest a south-to-north relationship with season. An August peak at Oxford and secondary August peaks at Water Valley and Riesel strongly suggest a late summer peak, possibly in response to crops drying and close grazing of grasslands.

Marlboro shows three peaks and a general undulant tendency, apparently reflecting weather and perhaps land use different from other sites.

Despite the August peak, possibly related to crops drying, Oxford rates correlate significantly with Tribune and Manhattan season indices (Table 5) but not with local wind and rainfall parameters.

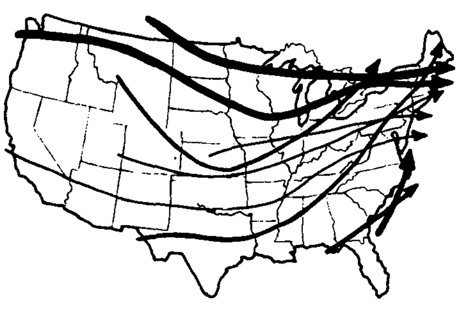
Relations of dust deposition to wind and rainfall were predominantly positive (Tables 3 and 4), especially to wind in the western part of the region. That is not surprising because the Great Plains probably is the source of most of the dust that is deposited over eastern and central USA. Wind measured at Dodge City, Kans., or Goodland, Kans., showed some stronger positive influences than wind near individual sites. Only Marlboro showed a zero or negative tendency with wind at Goodland. Marcellus showed a significant negative correlation with local wind but a nonsignificant positive tendency with western Kansas winds.

No single wind parameter was superior. Kansas sites, Akron, Colo., and an "all sites" comparison showed improved relations with increasing exponents through the fourth power of mean monthly wind velocity, but lower powers were equal or superior elsewhere.

All correlation tendencies between dust deposition and rainfall parameters were positive except at Coshocton (both traps) and Marcellus where R values were nonsignificant but negative, and wind velocity tendencies also were negative. Since wet soil and vegetative growth resulting from rainfall resist erosion by wind, it is impressive that rainfall correlated positively with dust deposition at so many sites. If negative influences of rainfall could be segregated and removed, positive influences at the same time might be stronger. Probably the main positive rainfall action is transporting particles to the earth in raindrops, which may account for most of the solids trapped.

Correlations were run for number of dusty days at North Platte, Goodland, and Dodge City versus dust deposition at each of the 14 sites, but the results were not included since most of the correlations were low or negative. However, the positive correlations obtained for Manhattan, Hays, and Tribune deposition versus dusty days at Dodge City, as well as Akron and Sidney deposition versus dusty days at North Platte, probably were not accidental.

Despite seasonal differences indicated, it is evident that positive dust deposition correlations predominate among sites. The only site showing a negative tendency with Manhattan deposition was Marlboro, which may be partially because Marlboro is south of the path taken by most cyclonic storms that traverse the Central Plains and the northeastern USA (Fig. 3).



TRACKS TAKEN BY MANY LOWS. AFTER VISHER, 1954.

Fig. 3—Tracks taken by many lows; width of line indicates relative frequency. (After Visher, S. S., 1954, Climatic Atlas of the United States, page 163, Harvard University Press [10]).

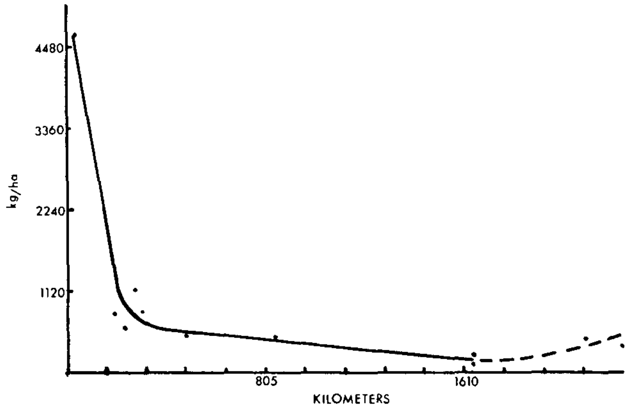


Fig. 4—Average annual dust deposition at several sites in relation to distance north and east from arbitrary dust bowl.

Low dust deposition rates at Water Valley suggest that much of the dust suspended from sandy soils only a short distance northward is swept predominately northward and northeastward by prevailing southerly winds and occasional cyclonic storms.

In mid-latitudes dust deposition rates tend to decrease eastward along the central storm tracks shown in Fig. 3. With the "Dust bowl" arbitrarily defined as a point on the Kansas-Colorado border 24.14 km west of Tribune, annual dust deposition rates so far determined north and east from that point are shown in Fig. 4. The most rapid decrease with distance is between Tribune and the next closest site, Hays, which has a somewhat lower rate than St. John or North Platte at slightly greater distances from the arbitrary point. Continuing eastward, the rate trend is downward through Manhattan, McCredie, and Coshocton (1,650 km or 1,025 miles). Beyond that point the relation to distance from western Kansas is lost as rates increase for Marcellus (2,090 km or 1,300 miles) and Marlboro (2,250 km or 1,400 miles).

Equations developed to predict dust deposition were judged partially successful. Using different combinations of variables, more than one-half of the variability in dust deposition at Akron, Hays, Manhattan, Marcellus, Riesel, Sidney, and Tribune was explained. About 46% of the variability at North Platte was explained while at Coshocton, McCredie, Marlboro, Oxford, and Water Valley the percentage variability explained was 35% or less.

Solution losses during processing reduced precision of the texture data. Since fine particles dissolve faster than coarse particles, it is likely that most solution losses were from clay-sized particles. If all material not weighed as silt and sand were clay size, the mean percentages of clay would range from 20.8% at Tribune to 47.3% at Water Valley. Certainly the clay percentages were not higher than those values and might be appreciably lower.

Median diameters in microns determined optically on silt plus sand fractions were: Manhattan, 16.0; Hays, 13.9; Tribune, 11.4; McCredie, 9.2; Akron, 8.8; Coshocton (N), 8.2; Coshocton (S), 8.3; Marcellus, 10.0; Marlboro, 9.7; North Platte, 11.7; Oxford, 11.5; Riesel, 9.7; Sidney, 13.0; and Water Valley, 11.9. Mean maximum diameters in microns by sites ranged from 139 at Sidney to 76 at McCredie (excluding aggregates).

It is not possible to say positively whether textures indicated by those optical measurements and clay estimates would qualify the dust deposits as texturally equivalent to loess, which, according to the often quoted suggestion of Russel (5), should consist by weight of at least 50% between 10 and 50μ diameter. Some averages, notably those for Tribune and North Platte, would qualify; but some, such as those for Water Valley, Coshocton, and Marlboro, probably contain too many fines to form loess as defined.

Weight losses from repeated treatment with hydrogen peroxide reflect partially decomposed plant and insect parts as well as soil organic matter. The weight losses may also reflect coke or other stack pollutants in some dust samples. Highest losses were for Marcellus, Oxford, and Marlboro. Seasonally, it appears that highest oxidation losses are for summer months (May through August) and lowest are from late fall to early spring (October through April).

Relatively high percentages of organic material in all stages of decomposition should strongly influence bulk density of deposited dust. It is reasonable to suggest that a similar admixture of low density organic material may have contributed to the high porosity frequently noted as characteristic of typical loess. In time the relatively undecomposed material would oxidize to a comparatively small amount of stable soil organic matter or humus but some of the original porosity would likely be retained.

Average pH reflects a west to east downward trend, similar to regional pH trends for soils, with lowest pH at Coshocton. However, lowest pH values do not indicate strong acidity.

An unexpected feature of clays was the low rating or absence of montmorillonite. The hydrogen peroxide pretreatment might have caused some degradation of montmorillonite. Equally surprising was kaolinite's consistent presence. As mentioned earlier, clay slides were relatively thin but that should not favor kaolinite over montmorillonite.

Kaolinite ratings averaged higher at Manhattan than at other sites, possibly reflecting kaolinite that is known to be prominent in Cretaceous rocks of west-central Kansas (2) and Colorado (6) and in Kansas river bars downstream from the region of Cretaceous exposures. At one point 161 km (100 miles) west of Manhattan, samples of sand and silty shales from the Dakota Formation of the Cretaceous were confirmed by the authors as containing abundant, well-crystallized kaolinite.

Generally high kaolinite ratings in dust may reflect the pickup by wind from immediate soil surfaces or selectivity of pickup by wind even from surfaces containing both montmorillonite and kaolinite. The relatively low surface activity, including weak cohesiveness and adhesiveness of kaolinite, should expose it to wind removal more readily than surface-active montmorillonite, which clings in aggregates. That would explain the lack of soil movement by wind in regions like the "Blacklands" (Vertisols) of Texas where montmorillonite dominates the clay (1).

Grass phytoliths were prominent in many dust samples and may be useful in distinguishing sites, seasonal changes, and dominant sources. Some detailed information on phytoliths comprises a separate paper (9).

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