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The Distribution of Climatic Factors in Iowa and Their Influence on Geomorphic Processes

By

Richard A. Karsten[1] and Sherwood D. Tuttle[2]

Abstract. This paper undertakes to evaluate effects of climate upon geomorphic processes in Iowa. Iowa's climate is described as humid continental long summer, with three-fourths of the annual precipitation falling between the end of March and the beginning of October. In almost all climatic factors, the variation trends or changes from the north-northwest toward the south-southeast.

Using the two parameters of mean annual temperature and mean annual rainfall for 119 stations in Iowa, a scattergram was constructed. Statistical analyses of the data suggest the presence of three microclimatic zones or regions in Iowa—northern, central, and southern. Comparisons of climatically controlled aspects of erosion and weathering showed that (1) drainage composition has had greater development in the south; (2) climatic factors affect the distribution and transportation of the dissolved and suspended load in streams; (3) soils of similar type and origin are more mature and have undergone more leaching of potassium, magnesium, and phosphorus in the southeast than in the northwest; (4) employment of the universal soil loss equation indicates that more soil is likely to be removed per acre by erosion in the southeast than in the northwest. In comparing degrees of erosion and weathering between the three microclimatic regions, slight differences become apparent, indicating that, in terms of climatic geomorphology, these regions are distinct.

We have chosen to examine the climate of Iowa to see if it has significant regional variations; and, if so, do these affect the modern landscape? While weather is apt to be a personal matter of wind velocity, rainfall, etc., climate—especially when described quantitatively—is an abstract generalization developed through the collection, collation, and analysis of great quantities of data. Within the patterns of climatic data are both seasonal and random variations.

Climatic geomorphology, in addition to explaining the present distribution of landscapes, may contribute analogs that can be used in historical geomorphology and other studies of ancient geologic events. Because most of the world's landscapes have developed since early Tertiary time (many are much younger), they have evolved through a span of time characterized by climatic shifts and variations of considerable complexity. Moreover, any investigation of process and climate must come to grips with the dilemma of whether the occasional catastrophic event accomplishes more than the steady everyday work of activities of small magnitude (Wolman and Miller, 1690). Statistical procedures and computer techniques are necessary in order to collate and evaluate the voluminous and

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complex data collected. Lastly, it was the intention of the authors that theoretical studies of this type be related to the real world.

That climate tends to control the type and rate of geomorphic processes has been part of geomorphological dogma since the days of William Morris Davis and his discussions of "climatic accidents." In arid environments and following episodes of glaciation, landforms and landscapes obviously reflect the influence of climate. Some authors have refined the concept of climate-controlled landscapes to include the recognition of semiarid, periglacial, and savannah environments. Other varieties of climatically related landscapes have been inferred.

Using data demonstrating that soil erosion was greater in a part of southern Indiana than it was in northern Indiana, Visher (1937) suggested that when other parameters were compensated for, climatic factors of higher rainfall and temperatures probably caused greater amounts of erosion to take place. Later (1945), Visher published a series of climatic maps of geologic interest that covered a wide range of parameters for the entire United States. Blumenstock and Thornthwaite (1941) diagrammed interrelationships between climate, vegetation, and soils. Büdel (1944, 1948) proposed the existence of "form-kreisen", or what may be called *morphogenic regions* or *climatomorphic regions*. In 1950 a tentative list of nine morphogenetic regions (based on two-axis plots utilizing mean annual rainfall and mean annual temperature) was proposed by Peltier, who suggested the most likely dominant geomorphic processes in each region (Fig. 1). According to Peltier, the landforms and landscapes unique to each region were largely produced by these dominant geomorphic processes in each region.

Chorley (1957) prepared an analysis of the morphometry of three areas in England characterized by similar gross lithology, structural effect, and stage of dissection but showing significant differences in landforms and landscapes. A climate-vegetation index obtained for each region was found to bear a remarkably consistent relationship to the mean logarithms of stream length, basin area, and drainage density that were likewise derived for each region.

Included among Thornbury's (1969) "fundamental concepts" is his statement that "an appreciation of world climates is necessary to a proper understanding of the varying importance of the different geomorphic processes." Nevertheless, as Thornbury points out (p. 28), ". . . surprisingly few detailed studies have been made that have attempted to show to just what degree climatic variations influence topographic details." To Thornbury, "the reason for this somewhat paradoxical situation is not apparent," but he suggests that "geologists in general are not climate-minded" and that geographers, "who are better acquainted with the details of climate, . . . have been more concerned with the adjustments of

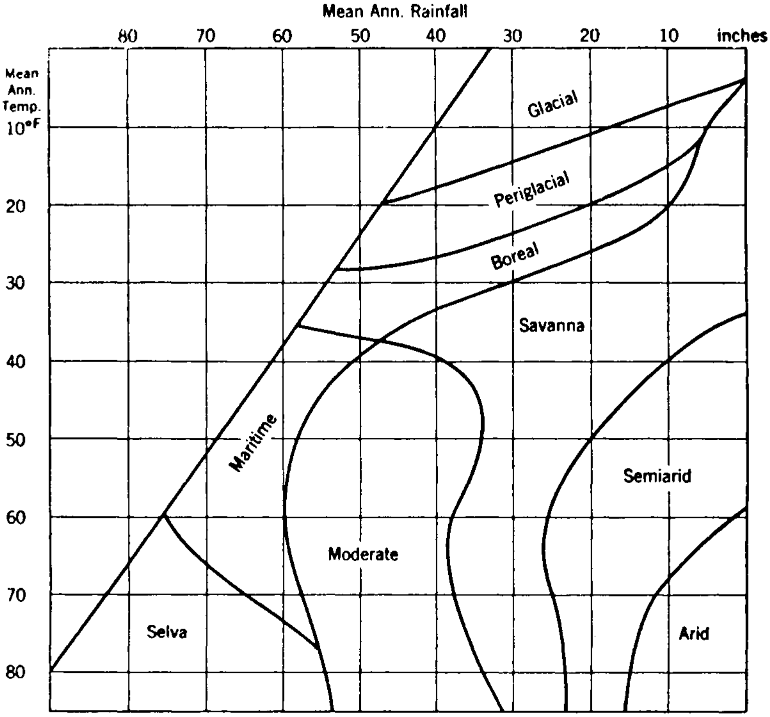

Figure 1 Diagram of climatic boundaries of morphogenetic regions (after Peltier, 1950).

man's activities to varying landscapes than with the origin of the landscapes themselves."

Climate of Iowa

Iowa's climate, according to the Köppen (1923) classification system, can be described as "humid continental long summer." Trewartha (1968) has classified the Iowa climate as "temperate continental warm summer." As is characteristic of this type of climate, 71 per cent of the annual precipitation occurs from April to September and 51 per cent from May to August (Reed, 1941). Unstable tropical maritime air masses bring about the long, warm, and humid summers; the cold, less humid winter months are under the influence of polar air masses.

We used 119 stations in Iowa to tabulate mean annual record years of precipitation (Fig. 2) and mean annual temperatures (Fig. 3). A discussion of Iowa's precipitation can be found in Waite (1970).

The percentage of annual precipitation occurring as runoff ranges from 14 to 22 per cent in northern Iowa, from 19 to 27 per cent in central Iowa, and from 17.5 to 22 per cent in southern

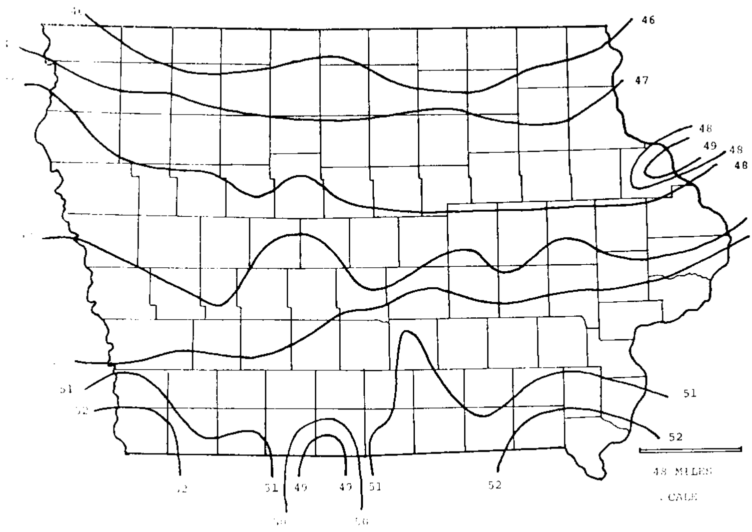

Figure 2 Mean annual precipitation for Iowa based on 119 stations.

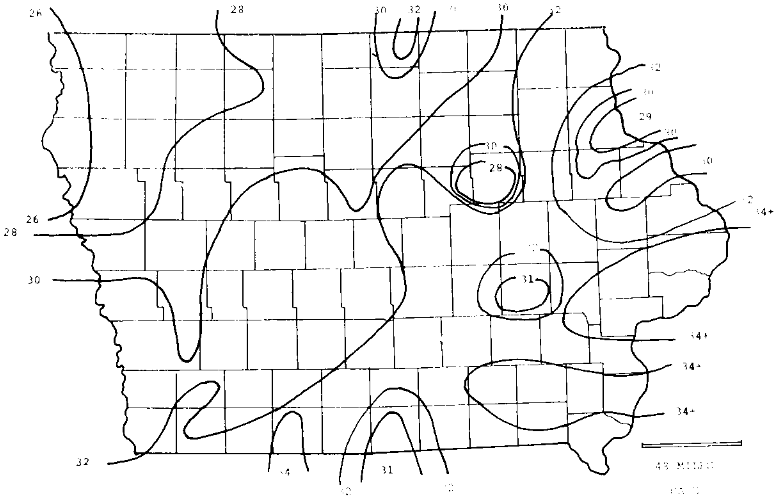

Figure 3 Mean annual temperature for Iowa based on 119 stations.

Iowa (Hidore, 1960). Wiitala (1970) has mapped the average annual runoff in Iowa (expressed as inches of precipitation) as ranging from two inches in the northwest to seven and one-half inches in the southeast, with eight inches in the east central area (Fig. 4).

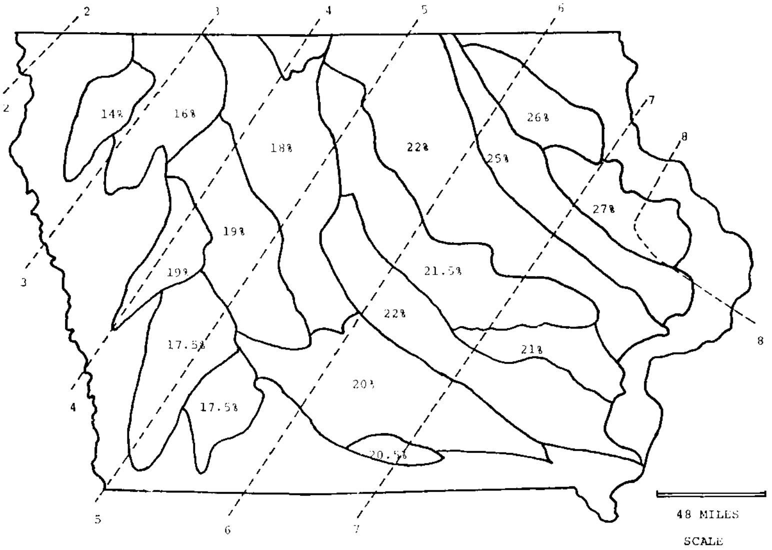

Figure 4 Runoff in Iowa, expressed as a per cent of annual precipiation by selected drainage basins (Hidore, 1960) and as inches of precipitation (Wiitala, 1970).

TABLE 1

Freeze-thaw data at six stations
in Iowa for the year 1960
(U.S. Dept. of Commerce, Weather Bureau, 1961)

	(1)	(2)	(3)	J	F	M	A	M	J	J	A	S	O	N	D
Sibley	202	89	75	6	7	9	12	2	0	0	0	0	8	21	10
Mason City	201	95	70	8	5	6	11	3	0	0	0	0	8	22	7
Carroll	196	83	87	11	4	8	12	1	0	0	0	0	13	23	15
Delaware	211	82	73	10	5	7	11	1	0	0	0	0	7	18	14
Clarinda	208	56	102	14	11	13	10	2	0	0	0	0	6	23	23
Mt. Pleasant	226	60	80	12	10	11	5	1	0	0	0	0	3	18	20
Monthly averages				10	7	9	10	1.6	0	0	0	0	7	21	16

(1) Number of days when the temperature did not go below 32° F.

(2) Number of days when the temperature did not go above 32° F.

(3) Number of days when the temperature crossed from above the 32° F. mark to below it.

(4) Number of crossings of temperature from above freezing to below freezing by months.

FREEZE-THAW FACTOR

Disintegration (mechanical weathering) brought about by the expanding force of water changing to ice is most effective as a geomorphic process in humid temperate climates where freezing occurs many times each year. For purposes of comparison, 1960 data (U.S. Dept. of Commerce, Weather Bureau, 1961) from three pairs of stations in northern, central, and southern Iowa were compiled as shown in Table 1. Frost occurred in all months except June, July, August, and September. At Sibley and Mason City in the north, temperature readings crossed from above freezing to below freezing 75 to 70 times respectively. At Carroll and Delaware in central Iowa, there were 87 and 73 crossings, while at Clarinda and Mt. Pleasant in the south, 102 and 80 crossings were reported. On the basis of these figures, it could be postulated that more disintegration and physical disruption, as well as mass wasting, would be caused by freezing throughout the south-southeastern area than in the localities farther north. Using the 70 crossings at Mason City as a low value, the 102 crossings at Clarinda represent a 46 per cent increase.

At all stations, January, April and November had the highest average number of crossings. Examination of the frost data also indicated that the number of days when the temperature did not go below freezing was slightly greater in south Iowa, and the number of days when the temperature remained below freezing all day was slightly greater in north Iowa. Thus, chemical weathering might have somewhat more time in which to operate in the south than in the north. In discussing freeze-thaw activity, Williams (1964) has stated the generally accepted hypothesis that "alternate freezing and thawing contribute to the development of the landscape wherever the process occurs with some frequency."

POSSIBLE CLIMATIC ZONES IN IOWA

The numerous indications of northwest to southeast trends in Iowa's climate patterns have suggested the possible existence of climatic zones which might differ significantly. In testing this hypothesis, the two major climatic factors, temperature and precipitation, were subjected to statistical analysis and were found to differ significantly across the state in a general northwest to southeast direction.

The first step in developing this schema was to plot the mean annual record years of temperature against the mean annual record years of precipitation (U. S. Department of Commerce Weather Bureau, 1964) for 119 stations in Iowa (Figs. 2 and 3). The method followed was that employed by Peltier (1950), with precipitation on the abscissa and temperature on the ordinate. Distribu-

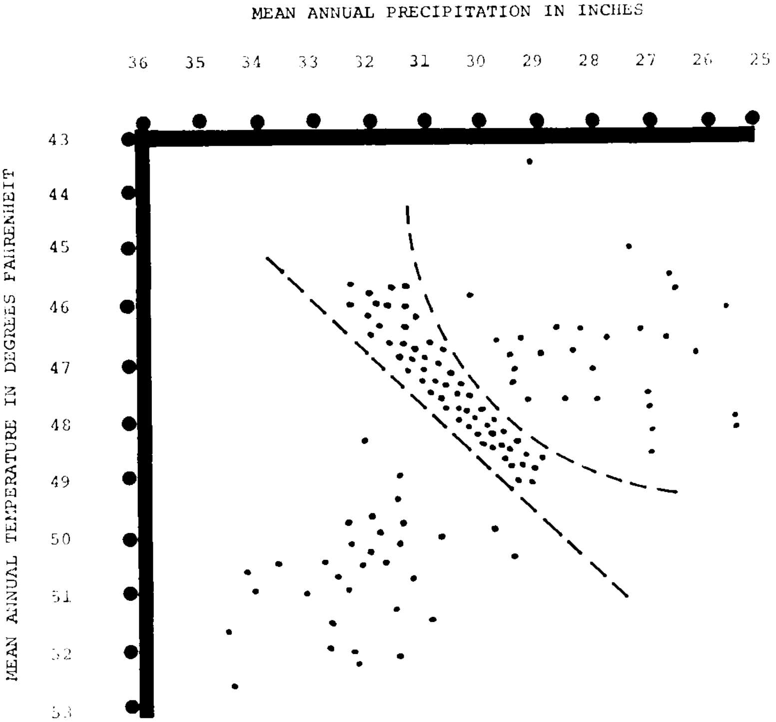

Figure 5 Scattergram of mean annual precipitation and mean annual temperature for 119 stations in Iowa (see Fig. 2) modified after Peltier, 1950.

tion of the 119 points (Fig. 5) derived from mean annual temperature and precipitation data suggested the presence of three climatic clusterings or zones in the state of Iowa.

These data were tested for normality, subjected to multiple discriminant analysis (Wittick, 1968) and to discriminant analysis-two group (Dixson, 1964). The data was normally distributed. The analyses allowed us to develop more discriminant groupings (Fig. 6). The F values were all statistically significant at the 95 per cent level of confidence.

In conclusion, the statistical analyses of temperature and precipitation data—these two parameters being the most important and most widely measured meteorological factors (Waite, 1970)—showed that three transitional climatic zones exist in Iowa. From a somewhat subjective first approximation, these zones evolved to a more refined delineation that was, in turn, carried to a second derivative regrouping by a second-level statistical analysis.

On Figure 6, the outlier of our northern microclimatic region in Blackhawk County (Waterloo) is probably the result of an

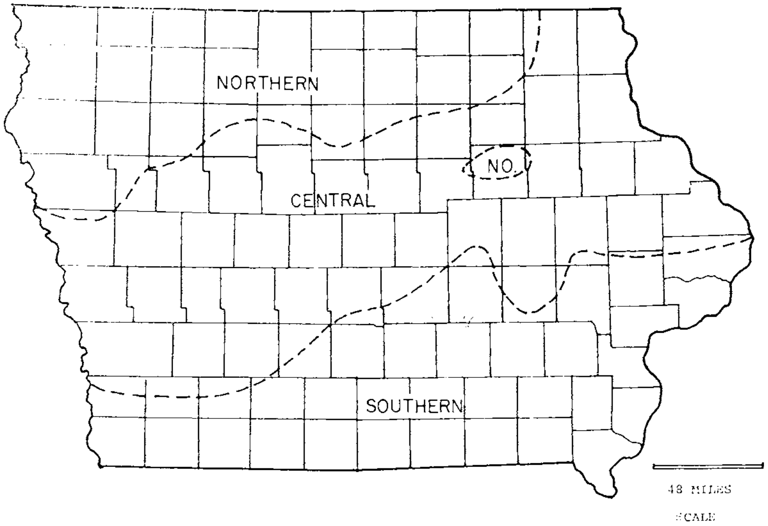

Figure 6 Microclimatic regions in Iowa developed from data gathered at 119 stations in Iowa.

area of lower precipitation (see Figure 3). A similar salient in Iowa County (Williamsburg) of the central region protruding into the southern region is also caused by an area of lower precipitation. An explanation for these two areas of lower precipitation is not apparent.

Examination of Climate-Process-Landscape Relationship

To examine the validity of the general northwest-southeast trend of climatic factors in Iowa, as well as the significance of the three microclimatic zones, the investigators considered four possible situations or conditions (as outlined below) in which climate might affect the type and rate of geomorphic processes:

(1) Differences in drainage composition (indicative of extent of erosion).

(2) Differences in dissolved and suspended solids in streams (indicative of amount of weathering and erosion).

(3) Differences in maturity—i.e., thickness and distinctness of horizons in soil profiles—and degree of leaching in soils (indicative of degree and rate of weathering).

(4) Application of universal soil loss equation (indicative of amount of erosion).

For discussions concerning climatic effects on geomorphic processes see Leopold, Wolman, and Miller (1964), Ollier (1969), and Holzner and Weaver (1965).

The geomorphic processes working on the Iowa landscape are modifying a basic framework sculptured during recent geologic history (Kay and Apfel, 1928, Kay and Graham, 1943, and Ruhe, 1969) that can be summarized briefly by the following major points.

(a) Glacial drift was deposited by ice sheets differing considerably in age. Kansan drift covering most of southern Iowa is probably ten times as old as the Wisconsin drift of the Des Moines lobe (Fig. 7) and is, therefore, much more heavily dissected.

(b) A much heavier loess blanket overlies the older drift than is found on the younger Wisconsin drift. This circumstance has had the effect of mantling the erosional topography developed on top of the Kansan drift.

(c) Surfaces of low relief have been developed by erosion over some areas of the Kansan drift (Iowan erosion surfaces) (Ruhe, Dietz, Fenton, and Hall, 1968).

(d) All of the loess and drift deposits have been dissected in some degree—some much more than others—by glacial meltwater, and by interglacial and postglacial runoff.

Therefore, with the dominant factors in the shaping of the Iowa landscape being glaciation, fluvial processes, and wind deposition, any effects of variation in present climate tend to be obscured by the results of former climatic regimens. Direct field evidence, such as differences in rock weathering, regional stages of erosion, depths of valleys, etc., cannot serve as direct evidence to test the effects of present climatic variations in Iowa.

Comparisons of Drainage Composition

So as to minimize the factor of types of regolith (glacial drift, loess, etc) only drainage developments on areas of similar material and age were compared. These restrictions plus the limited availability of 1/24,000 topographic maps in Iowa allowed only a few possible comparisons to be made. Four pairs of areas were selected and measured (Fig. 7) with one pair coming from each of the following regions.

(1) Loess depositional topography east of the Missouri River in western Iowa.

(2) Young drift depositional topography of the Des Moines lobe.

(3) Iowan erosion surface.

(4) Loess-mantled erosional topography on the Kansan drift in southern Iowa.

In all cases an attempt was made to compare areas having similar characteristics. On the Des Moines lobe, for example, both areas were on Cary ground moraine rather than end moraines. In order to reduce the effect of local baselevel, all areas selected

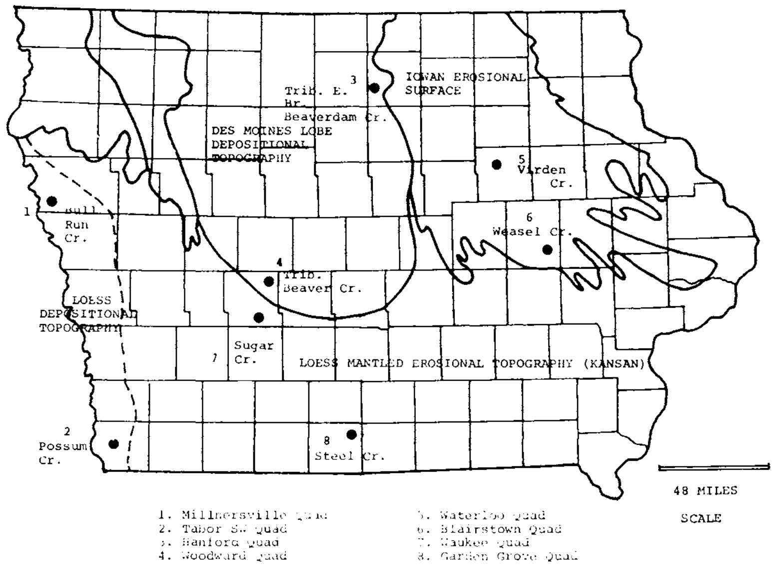

Figure 7 Locations of small drainage basins used in comparisons of drainage compositions. Glacial boundaries after Iowa Geological Survey (1955).

were as far away as possible from major drainages. Each member of each pair of basins is as close to the other in size as could be found. Three of the pairs are located so that one basin is both to the south and east of the other. Only in the case of the basins of the tributary of Beaverdam Creek near Mason City and the tributary of Beaver Creek near Woodward was the southerly basin selected slightly west of the northern one. The purpose of making selections in this way was to see if the general northwest-north to southeast-south changes in climate might affect the development of the topography in these areas (Fig. 7). Also, one basin of each pair lies in a different microclimatic region from the other so that the validity of the three zones may be evaluated.

The procedures and laws of Horton and Strahler, as applied to small drainage basins, were employed in comparing drainage compositions. Care was taken to extend all stream lines headward, and then all stream numbers and stream lengths were counted and measured. From these data, stream frequency and drainage density were calculated for each basin (all but one were 5th order basins) and the values compared (Table 3). Higher values for stream frequency and drainage density were found for the more southerly basins in each pair. Basin relief and a roughness index did not show the same increasing degree of downcutting and roughness toward the south as did stream frequency and drainage density.

TABLE 2

Comparison of drainage composition

Loess depositional topog.	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bull Run Cr. Basin (Millnersville Quad.)	21.2	4.6	10.0	320	6.9	150	N
Possum Cr. Basin (Tabor S.W. Quad.)	41.0	5.9	7.2	290	6.9		S
Des Moines Lobe depositional topog.							
Trib. E. Br. Beaverdam Cr. Basin (Hanford Quad.)	10.0	4.2	5.2	90	2.6	80	N
Trib. Beaver Cr. Basin (Woodward Quad.)	37.0	7.3	4.5	180	5.1		M
Iowan erosion surface							
Virden Cr. Basin (Waterloo N. Quad.)	18.5	4.0	11.2	180	3.4	55	N
Weasel Cr. Basin (Blairstown Quad.)	33.2	4.6	8.7	140	2.7		M
Loess-mantled erosional topog. (Kansan)							
Sugar Cr. Basin (Waukee Quad.)	18.9	3.3	11.0	120	5.1	60	M
Steel Cr. Basin (Garden Grove Quad.)	27.4	4.0	11.5	140	4.2		S

(1) Steam frequency, number of streams per square mile
(2) Drainage density, miles of stream per square mile
(3) Basin area, square miles
(4) Basin relief, feet
(5) Roughness index, basin relief divided by horizontal distance between points used to calculate basin relief.
(6) Distance between sample areas in miles
(7) Microclimatic region

Thus the conclusion can be drawn that in the areas of Iowa with more rainfall and more frequent freezing and thawing, the drainage composition (as indicated by stream frequency and drainage density) is more advanced or better organized.

Further examination of the drainage composition data in Table 2 reveals several aspects of the general development of drainage in Iowa. The general decrease in bifurcation ration with increasing order suggests that the drainage is not yet very well organized or integrated. This is to be expected in landscapes that are immature or in disequilibrium. The occurrence of occasional erratic growth of average stream lengths and stream length ratios with increasing orders is likewise indicative of disequilibrium. Since in gathering data, basin areas were chosen before the streams were ordered, the lengths of the highest order streams are not correct because the 5th order streams were not carried downstream until they reached a 6th order stream.

The lack of agreement of basin relief and roughness indices with the increases in rainfall and higher temperatures may also indicate an overall lack of organized integration of drainage nets.

DISSOLVED AND SUSPENDED LOAD IN STREAMS

Although dissolved and suspended solids in the streams of Iowa are primarily a function of materials and morphology, climatic factors should affect the distribution and transportation of the dissolved and suspended load.

Published data about suspended and dissolved solids in Iowa stream waters (U. S. Geological Survey, 1969) is inconclusive in terms of the questions asked in this paper. Burmeister (Assistant District Chief, U.S. Geological Survey, Iowa City, Iowa) hypothesized that in the more arid, less temperate north and northwest part of the state, both suspended and dissolved solids are introduced into the streams in an irregular pattern that reflects the slower thawing of frozen regolith and the lower amounts of precipitation. In the less arid, more temperate south and southeast part of Iowa, solids are introduced into the streams in more of a continuum because of earlier thawing of the regolith and more precipitation. The central region is a zone of transition where total solids are washed into or dissolved in streams in a more regular pattern than in the northern region but a less regular pattern than in the southern region (oral communication, Ivan Burmeister, 1970). The regions discussed above agree grossly with the pattern of microclimatic regions described in this paper.

LEACHING AND SOIL PROFILES

Data from research in agronomy carried out by investigators at Iowa State University have provided a basis for comparisons of soil profiles from which climatic effects can be inferred. Percentages remaining of soluble potassium, magnesium, and phosphorus were measured and compared between soils of similar parent material (loess) of about the same age (Tazewell) located in similar topographic positions (i.e., formed under prairie grasslands on level upland landscapes). Comparing non-exchangeable magnesium among several soil profiles, Protz and Riecken (1968) concluded that the magnesium content increases in depth within soil profiles. Using five examples, Protz and Riecken indicated that more magnesium has been removed from profiles in the Otlay, Mahaska, and Taintor soils than from profiles in the Galva and Primghar soils.

The data obtained also showed that the base of the B horizon is deeper in the Otley, Mahaska, and Taintor soils than in the two others. Thus in the cases of these loess-derived, prairie-formed upland soils of Iowa, it would appear that more leaching has occurred in the southeastern part of the state; and since the base of the B horizon is deeper in this area, the soil profiles are somewhat more mature. In terms of geomorphic processes, leaching and other complex weathering activities of soil formation are greater in the southeast. Since, as has been stated, other conditions are about the same, this increase in the intensity of weathering is probably due to climatic factors—that is, more rainfall, higher temperatures, more frequent freeze and thaw.

A similar study involving the regional distribution of potassium in B horizon clay (Wills and Riecken, 1969) suggests a parallel conclusion. Comparing the total potassium remaining, the profiles of Tama, Otley, Mahaska, and Taintor soils show less potassium (1.56, 1.59, 1.56, 1.64, 1.52, and 1.53 per cent) than do the Macksburg, Winterset, and Marshall soils of western Iowa (1.90, 2.13, 2.00, and 2.02 per cents). Wills and Riecken examined 16 profiles from loess-derived soils—all about the same age and formed under prairie vegetation on level upland sites—and drew the following conclusion:

> "The results of our study have shown that there are differences in total K content of prairie loess soils that were selected to minimize differences due to time of soil formation. We feel that differences in K are related to differing degrees of intensity of the kinds of soil-forming processes operative regionally. This is primarily due to differences in annual precipitation."

In the case of phosphorus in Iowa soils, Runge and Riecken (1966) compared the per cent of total phosphorus in soil profiles using Winterset, Macksburg, and Sharpsburg soils in the west and Taintor, Mahaska, and Otley in the east. As in the previous examples, all soils compared are loess-derived, of Tazewell age, and formed under prairie vegetation on level upland landscapes. The comparison showed that the western soils have a higher total phosphoric value in most horizons than do the eastern soils. Runge and Riecken, in explaining the difference, commented: "Whether the chemical differences of the two sequences are caused mainly by climate needs further verification, but our data, together with other data, merit consideration that the differences are due to climate."

Riecken (Professor of Agronomy, Iowa State University Ames, Iowa) added (written communication, 1970): "I think it is reasonable to conclude that climate has its effects on soils in Iowa, but it is difficult to isolate possible effects of other factors such as composition of original sediments, time of weathering, etc., with the existing data."

THE UNIVERSAL SOIL LOSS EQUATION

Thoreson and Maddy (1963) have published revised equations predicting the average soil losses that might be expected over a period of years. The equations were developed from basic data covering a period of 22 years and involving actual soil losses and rainfall data from 37 states. When (1) the rainfall factor, (2) the soil erodibility factor, (3) length and steepness of slope, (4) cropping management factor, and (5) a supporting conservation factor are put into an equation, the predicted average annual soil loss in tons per acre may be calculated. In 1967, Ballantyne, Schaller, and Phillips, in a paper discussing soil erosion, applied the soil loss equation to Iowa and presented tables based on experience by which the number of tons of soil lost per acre can be calculated.

TABLE 3

Predicted soil losses in Iowa using The universal soil loss equation

$A = RKLSCP$

Location County	R	K	L	S	C	P	
O'Brien	160	.32	2	10°	.30	.60	14.8 tons
Pocahontas	160	.32	2	10°	.30	.60	14.8 tons
Franklin	160	.32	2	10°	.25	.60	12.3 tons
Carroll	160	.32	2	10°	.30	.60	14.8 tons
Story	180	.32	2	10°	.30	.60	20.8 tons
Linn	180	.32	2	10°	.25	.60	17.2 tons
Union	180	.43	2	10°	.30	.60	27.8 tons
Wapello	200	.43	2	10°	.25	.60	25.2 tons
Henry	200	.37	2	10°	.25	.60	21.6 tons

A—average annual soil loss in tons per acre predicted by the equation.

R—rainfall factor (a value of 160 for north and northwest Iowa, 180 for central Iowa, and 200 for southeastern Iowa).

K—soil erodibility factor (this varied across Iowa from 0.32 on the Galva silty clay loam in O'Brien county up to 0.43 for Adair clay loam in Union County.

L—length of slope factor. (we used 200 feet in all cases)

S—steepness of slope factor. (we used 10° in all cases)

C—cropping and management factor (assuming a "fall plow for row crops, residue removed, small grain seeded in disked row stubble in spring, with a cropping system of row crops, small grains, and meadow" management and yield level and cropping system, this factor is 0.30 in western Iowa (area 13) and 0.25 in eastern Iowa (area 14).

P—practices factor; i.e., whether contour plowing, strip cropping or terracing are used. (In all our calculations the same P factor was used.)

Examination of Table 3 reveals a definite increase in the prediction for the average amount of soil that may be eroded as one goes generally southeastward from northwest Iowa. The three localities lying in the northern microclimatic region average 13.9 tons; in the central region, 17.6 tons; and in the southern region, 24.9 tons—in other words, an increase of over 50 per cent from northwest to southeast. The agreement between the grouping in Table 3 and our microclimatic regions—with a colder, dryer environment in northwest Iowa and a warmer, wetter regimen in southeast Iowa—strongly suggests that the difference in the rainfall-temperature parameters may explain the variation in soil erosion.

CONCLUSIONS

1. Three slightly different microclimatic zones or regions were identified in Iowa, based on statistical analyses of mean annual temperature and mean annual rainfall data. This finding supports the generalization that climate varies from north northwest to south southeast in Iowa.

2. Examination of selected aspects of drainage composition suggests that erosion has progressed farther and become better integrated in the southern and southeastern parts of the state.

3. Patterns of the distribution of dissolved and suspended solids in streams are related to climatic parameters in an irregular manner in the north and in a more continuous or regular manner in the south.

4. Soils formed on materials of similar type and age tend to be more mature (using as a criterion the depth to the base of the B horizon) in the south and southeast. Also, leaching of potassium, magnesium, and phosporus is more intense and has extended deeper in the south and southeastern areas.

5. The universal soil loss equation predicts more soil erosion in the south and southeast than in the north and northwest.

6. When the dominant controlling factors of age and type of material are similar, the effect of differing climatic environments tends to influence the type and rate of geomorphic processes. Timing and distribution of climatic factors may accelerate or retard the total effects of the geomorphic processes.

7. The findings from drainage composition data, suspended and dissolved solids in streams, soil depths and leaching, and predicted soil losses all indicate greater activity or intensity of processes trending from northwest to southeast, thus supporting the validity of the three microclimatic zones as being distinct in terms of climatic geomorphology.

References Cited

BALLANTYNE, C. R., SCHALLER, F. W. & PHILLIPS, J. A., 1967. *Erosion control factors and the universal soil loss equation:* Cooperative Extension Service, Iowa State University, Ames, Pm-410.

BLUMENSTOCK, D. I., & THORNTHWAITE, C. W. 1941. Climate and world pattern: *in* Climate and Man, 1941 Yearbook of Agriculture, U.S. Department of Agriculture, Washington, D.C., p. 79-92.

BUDEL, J., 1944. *Geol. Rundschau,* **34**:482-519.

————————. 1948. *Geogr. Rundschau,* **7**: 269-286.

CHORLEY, R. S., 1957. *J. Geol.,* **65**: 628-638.

DIXSON, W. J., 1964. *BMD computer programs manual.* U.C.L.A., Los Angeles.

HIDORE, JOHN J., 1960. The water resource base of Iowa: unpub. Ph.D. dissertation, The University of Iowa, Iowa City, 89 p.

HOLNZER, LUTZ & WEAVER, G. D., 1965. *Assoc. Am. Geog. Annals,* **55**:592-602.

IOWA GEOLOGICAL SURVEY, 1955. *Generalized sketch map of the glacial geology of Iowa.* Iowa City, Iowa.

KAY, GEORGE F., & APFEL, EARL T., 1928. The pre-Illinoian pleistocene of Iowa: Iowa Geol. Survey Ann. Rpt., 1928, v. 34, 304 p.

KAY, GEORGE F., & GRAHAM, JACK B., 1943. *Iowa Geol. Survey Ann. Rpts.,* 1940-1941, **38**:116-22.

KOPPEN, WALDIMIR, 1923, *Die Klimate der Erde; Grundriss der Klimakunde.* Walter de Gruyter, Berlin.

LEOPOLD, LUNA B., WOLMAN, M. G., & MILLER, JOHN P., 1964. *Fluvial processes in geomorphology.* W. H. Freeman and Co., San Francisco. 522 p.

OLLIER, C. D., 1969. *Weathering.* American Elsevier. New York.

PELTIER, L. C., 1950. *Assoc. Am. Geog. Annals,* **40**:214-236.

PROTZ, R., & RIECKEN, F. F., 1968. *Soil Sci. Soc. Am. Proc.,* **32**:861-865.

REED, C. D., 1941. Climate of Iowa: *in* Climate and Man, 1941 Yearbook of Agriculture, U.S. Department of Agriculture, Washington, D.C., p. 862-872.

RUHE, R. V., DIETZ, W. P., FENTON, T. E. & HALL, G. F., 1968. *Iowan drift problem, northeastern Iowa:* Iowa Geol. Survey, Rpt. Inv. 7.

RUHE, R. V., 1969. *Quaternary landscapes in Iowa.* Iowa State University Press, Ames, 255 p.

RUNGE, E. C. A., & RIECKEN, F. F., 1966. *Soil. Sci. Soc. Am. Proc.,* **30**: 624-630.

THORESON, A. S. & MADDY, J. K., 1963. *J. Soil Water Conserv.* **18**:159-160.

THORNBURY, W. D., 1969. *Principles of geomorphology.* John Wiley and Sons, New York.

TREWARTHA, GLENN T., 1968. *An introduction to climate.* 4th ed., McGraw-Hill Book Co., New York.

U. S. DEPARTMENT OF COMMERCE WEATHER BUREAU, 1961, Climatological data, Iowa: v. **71**, Washington, D.C.

————————, 1964. Decenial census of United State climate, climatic summary of the United States, *in* Climatography of the United States. No. 86-11, Washington, D.C., 84 p.

U. S. GEOLOGICAL SURVEY, 1969, *Water resource data for Iowa, part II, water quality records.* Washington, D.C.

VISHER, S. S., 1937. *Geol. Soc. Am. Bull.,* **48**:897-929.

————————, 1945. *Geol. Soc. Am. Bull.,* **56**:713-736.

WAITE, P. J., 1970. Iowa precipitation: *in* Water Resources of Iowa, ed. P. J. Horick, Iowa Acad. Sci., p. 3-15.

WELLS, K. L., & RIECKEN, F. F., 1969. *Soil Sci. Soc. Am. Proc.,* **33**:582-587.

WIITALA, S. W., 1970. Surface water resources of Iowa: *in* Water Resources of Iowa, ed. by P. J. Horick, Iowa Acad. Sci., p. 17-28.

WILLIAMS, L., 1964. *Assoc. Am. Geog. Annals,* **54**:597-611.

WITTICK, ROBERT I., 1968. *Manual of computer programs.* Spec. Pub. No. 1, Dept. of Geog., Univ. of Iowa, Iowa City, 65 p.

WOLMAN, M. G., & MILLER, J. P., 1960. *J. Geol.,* **68**:54-74.