Indiana Regional Contrasts in Soil Erosion and Their Chief Causes

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Introduction.—*The Problem:* How great are the regional contrasts in Indiana with respect to soil erosion? What influences have caused the contrasts? What is the relative significance of each of the more important factors? *The Method:* An analysis has been made of the map of soil erosion issued in 1935 by the Soil Conservation Service, and some of the findings are shown on ten maps reproduced here. Maps of several factors suspected of helping to cause erosional contrasts were made and compared with the erosion maps. *Conclusions:* There are very notable regional contrasts in soil erosion in Indiana. Some of these are correlated with contrasts in local relief, others with the soil types, others with the recency of glaciation, and others with land use. Regional contrasts in rainfall intensity, a factor hitherto not discussed as important, appear to be of notable significance in causing part of the observed contrasts. (A more detailed summary closes this paper.)

Although very little of Indiana has been cultivated for as much as a century, nearly half of the state has suffered extensively from soil erosion. This has happened as a result of the type of agriculture that has prevailed, the relatively large amounts of rainfall received during the cooler months, and the fact that at least half of the state has sufficient slope to permit fairly rapid runoff whenever there is considerable rainfall.

As Indiana is representative of a considerable area in the midwest, the Soil Conservation Service of the United States Department of Agriculture has deemed it worth while to make a special study of the soil erosion in this state. The present writer (formerly a Scientist in the U. S. Bureau of Soils) spent the past summer upon a study of the regional contrasts in erosion in Indiana, with special attention to the factors that caused the contrasts. This study had two phases: first, field work in all of the counties; and, second, an analysis of the map showing the amount of erosion, and of data of various sorts that might help explain the contrasts. The report, when completed, will treat in considerable detail of various factors.

In the present paper, there is space for only a brief analysis, largely by means of maps, of the erosional contrasts and of some factors that have contributed to cause the contrasts.

First, a few statements concerning the state as a whole: About 43% of Indiana has suffered considerable erosion, having lost more than one-fourth of its original topsoil, on the average. Three great types of erosion are extensive, namely sheet erosion, gullying, and wind erosion. Sheet erosion is more widespread than gullying, as about 40% of the state has suffered rather serious damage from sheet erosion in contrast to about 31% which has been somewhat gullied. As all the gullied areas are also subject to sheet erosion, the 31% of the state that is gullied is included in the 40% where sheet erosion is considerable. Wind erosion

is also of local significance, and some 650,000 acres, or nearly 3% of the state, have been damaged by wind erosion.

The extent of erosion damage: From one-fourth to three-fourths of the original thickness of the topsoil has been widely removed[1] by sheet erosion in one-third of the state; from an additional 7% of the state, more than three-fourths of the topsoil is generally gone. A fifth of the state has what the Soil Conservation Service officially classes "occasional" gullies, and one-ninth has "frequent" gullies, or severe gullying. Wind erosion has seriously damaged some 30,000 acres.

An Analysis of the Erosion Data

The statements of the amount and kind of erosion here given are based on a study of the reconnaissance erosion survey map of Indiana recently issued by the Soil Conservation Service. This large map is quite complicated. Planimeter measurements have now been made of the areas of each type of erosion mapped. The percentages that each erosion type makes up of the total area of each county have also been calculated, and are used as the basis for several of the following maps. The analysis of erosional contrasts may appropriately commence with

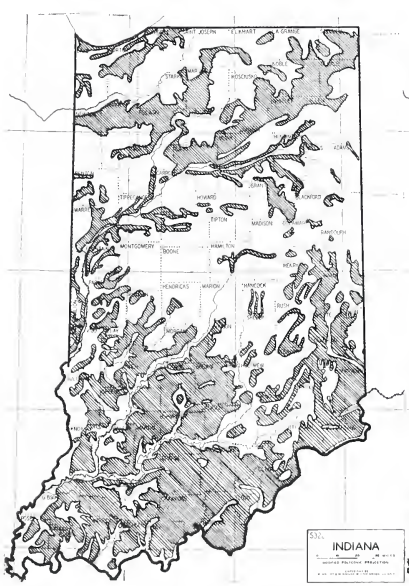

Fig. 1. Erosion map. Unshaded areas have in general little or no serious erosion as compared with the shaded areas. (Adapted from the map of the Soil Erosion Survey by the Soil Conservation Service.)

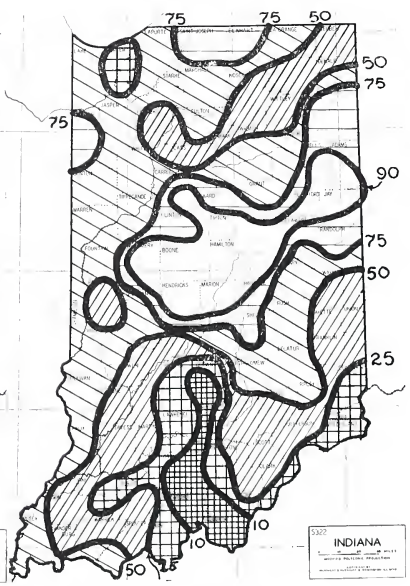

Fig. 2. Percentage of each county having little or no serious soil erosion. (Based on planimeter measurements of the large map just mentioned.)

[1]A square mile is classified as of a given erosion type if as much as 25% of its area belongs to that erosion type. The above statements do not mean, for example, that a large share of all the topsoil has been removed from every acre of one-third of the state but, instead, that in one-third of the area of the state this type of erosion prevails on at least one-fourth of each square mile.

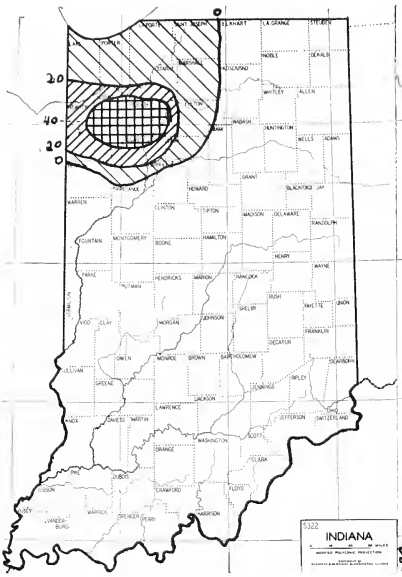

Fig. 3. Wind erosion. Percentage of each county where considerable areas are damaged.

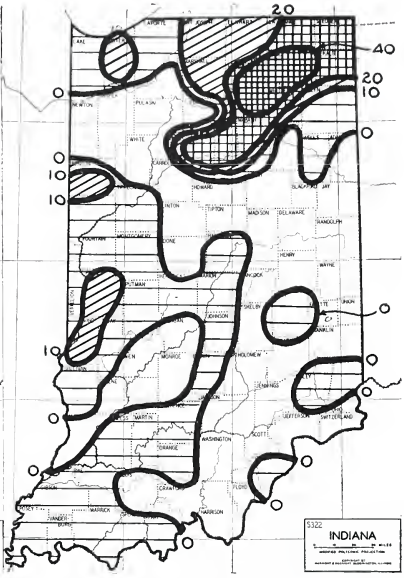

Fig. 4. Sheet erosion without gullying. Percentage of each county in which this type prevails.

the distribution and relative extent of the areas upon which there has been, in general, little serious soil erosion. Figure 1, adapted from the soil erosion survey map just mentioned, shows two types of area. Those left unshaded have suffered little erosion as compared with the shaded areas, which have considerable erosion. (Some of the unshaded areas along the rivers in the southern half of the state are somewhat too wide; likewise within the shaded and unshaded areas there are small areas of the opposite type, too small to be shown on this scale.) This map indicates that most of the extensively eroded land is in the southwestern third of the state, in parts of the southeast, and in various wide bands in the north. Conversely, the areas that are little eroded are largely in the central part of the state.

Figure 2 shows the percentage of the area of each county which was classed as subject to little erosion. This map indicates some of the sharp regional contrasts more effectively than does Map 1. The chief areas in which less than one-quarter of the land is classed as being notably eroded are in central and northern Indiana. The percentages for various counties, not given on the map since they would be scarcely legible at the scale used, may be mentioned: Tipton and Boone 100%, Blackford 98, Madison 97, Marion 96, Hendricks and Montgomery 93, Carroll 92, Jay and Wells 89, Adams 88, Randolph 86, Shelby 84, Howard 83, Allen 82. Conversely, counties with small percentages of uneroded land are Crawford 0.6%, Orange 5, Harrison 6, Brown 8, Pike 11.

Figure 3 shows the percentage of the area which has suffered appreciably from wind erosion. Although some small sandy areas in

Jackson County and in the southwest (Knox and Gibson counties) have suffered from wind erosion, the only counties that have had as much as 1% of their area damaged by wind erosion are near the northwestern corner of the state. There, 44% of Pulaski County, 43% of Jasper, 28 of White, 23 of Newton, 19 of Lake, 11 of Marshall, and from 1% to 6% of five adjacent counties have been notably damaged by wind erosion.

Figure 4 treats of sheet erosion which is not accompanied by appreciable gullying. This map shows that in the northeastern counties from 10 to 40% of the area has generally lost one-fourth or more of its original topsoil by sheet erosion without gullying. Except in two small areas, one in the northwest and the other in the west-central parts of the state, no other counties have simple sheet erosion upon as much at 10% of their area; indeed most counties have less than 1% of their land eroded in that way.

Figure 5 shows sheet erosion accompanied by gullying as well as that without gullying. It has a very different appearance from Figure 4, because most sheet erosion is accompanied by gullying. This map shows that half or more of the area of each of the southern counties has suffered considerable ("moderate" or "severe") sheet erosion, and that 75% or more of several south-central counties have so suffered. Crawford County is almost all (99%) subject to considerable sheet erosion. Other high counties, with the percentage of their area classed as having considerable sheet erosion on a large part of each square mile, are Orange 98, Brown 92, Pike 87, Dearborn 82, Lawrence and

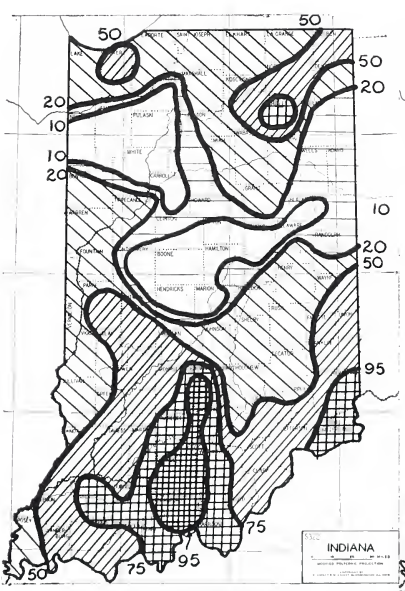

Fig. 5. Sheet erosion without or with gullying. Percentage of each county distinctly affected.

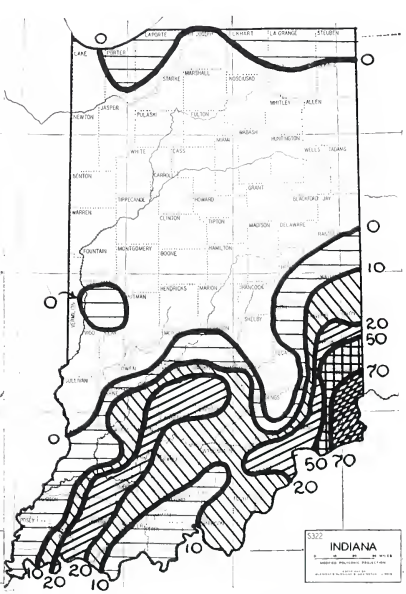

Fig. 6. Severe sheet erosion. The relative abundance of this type of soil loss.

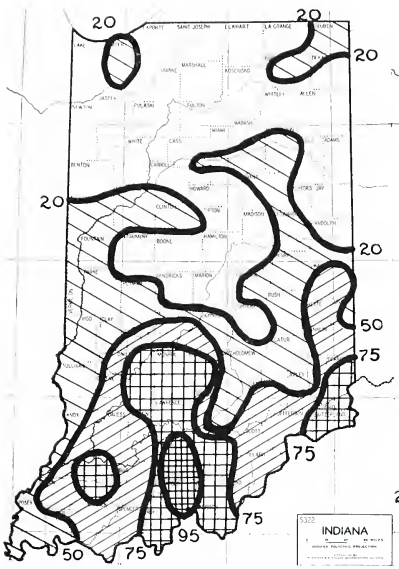

Fig. 7. Gullying. The percentage of each county affected by gullying.

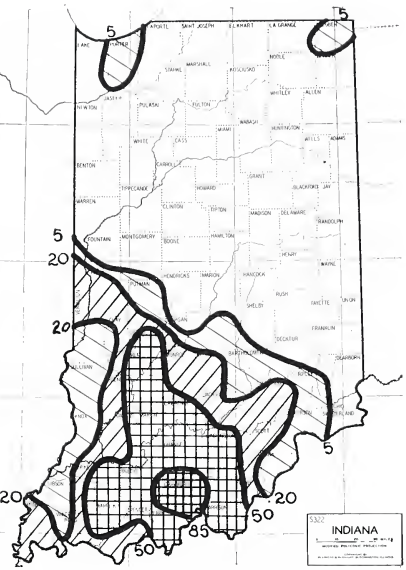

Fig. 8. Frequent gullies. The relative proportion of land cut by frequent gullies.

Switzerland 79, Perry and Ohio 78, Harrison 77, Washington 76, Owen 74, Monroe 73, Floyd and Noble 72, and Martin and Clark 71.

Figure 6, which illustrates severe sheet erosion (three-fourths or more of the original topsoil gone) reveals that this type of erosion is almost confined to the southeastern third of the state, together with four counties on the Michigan border. Severe sheet erosion is worst at the southeast corner, where 77% of Dearborn County, 76% of Ohio, 69% of Switzerland, and 58% of Franklin are classed as of this erosion type. However, further west are five counties in this same category: Dubois with 52%, Scott 42, Vanderburg 34, Martin and Brown 20.

Gullying

Figure 7 concerns the distribution of gullies. Gullying is very widespread; only four counties were mapped by the erosion survey as lacking sizeable areas that were gullied. These were Tipton, Boone, Newton, and Jasper. Counties with only about 1% of their land somewhat gullied are Pulaski, White and Marion. Other fortunate counties in this respect, with their percentages, are Blackford 2, Madison 3, Hendricks and Montgomery 4, Starke 6, Marshall 7, Carroll 8, and the following 9 each: Benton, Hamilton, Kosciusko, Lagrange, Wells. By contrast, most of the counties of the southern half of the state have 40% or more of their land somewhat gullied. The least fortunate counties in this respect, with the percentages of their areas of this type, are Crawford 99, Orange 96, Brown 92, Pike 86, Dearborn 81, Switzerland and Lawrence 79, Harrison 78, Washington and Ohio 77, Monroe 76, Perry 75, and Owen 74.

Two types of gullying were distinguished by the erosion survey, namely "occasional" and "frequent" gullies. The percentage of the land with occasional gullies is greatest at the extreme southeast, where nine counties have more than half of their land in this type. These extend from Wayne to Clark counties. Switzerland, Ohio, and Dearborn counties each have 77 to 79% of their land of this type. The only other counties with half or more of their land classed as eroded by occasional gullies are Brown 66, Orange 55 and Gibson 50.

Figure 8 shows the percentage of the area classed as having frequent gullies. This map reveals that severe gullying is largely confined to the southwestern third of the state. Ten counties near the center of that section have more than half of their land of this type. Crawford County has 89% of its area of this type, frequent gullies on a large share of each square mile. On the other hand, more than half of the counties of the state have no considerable tracts of badly gullied land. The counties reported by the erosion survey as having small areas of this type may advantageously be listed, since by so doing, the counties which have no appreciable area of this type are indicated indirectly, namely the remaining counties of the area shown on Map 8, as having less than 5% of their area with frequent gullies. Counties with about 4% of this type are Cass, Wayne, and Dearborn; with 3%, Huntington, Montgomery, and Laporte; with 2%, Lagrange; and with some areas, but less than 1.5%, Elkhart, Noble, White, Carroll, Wabash, Fountain, Henry, and Sullivan.

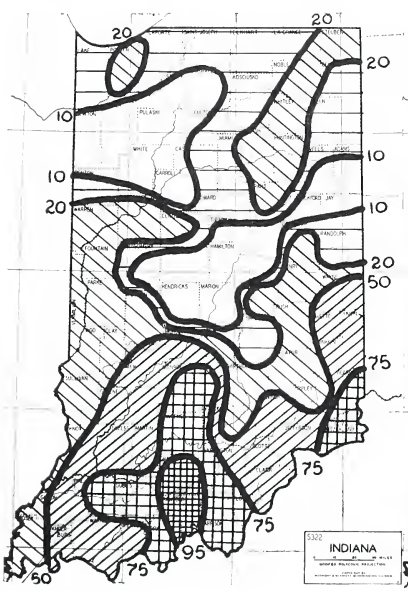

Fig. 9. Considerable sheet erosion and gullying. The percentage of each county in which these two types of soil destruction prevail.

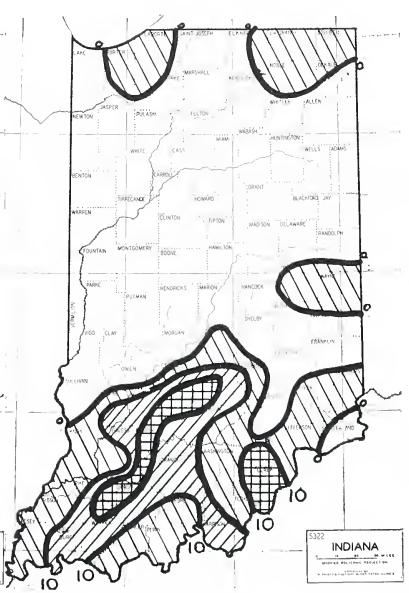

Fig. 10. Frequent gullies and severe sheet erosion. The relative proportion of the land being destroyed by these types of erosion. Correction: the elongate, double crossed area is 20+; the smaller one is 10 to 20.

Since gullying and sheet erosion generally occur simultaneously, on the same land, Figure 9, showing the percentage of each county having considerable of both erosion types, is of special interest. These percentages of their areas have in general lost more than one-fourth of their original topsoil by sheet erosion, and also have occasional or frequent gullies. This map shows that more than half of the area of most of the southern counties is of this type. Some ten south-central and three southeastern counties have over 75% of their areas in this category, and near the center of the south-central area, Crawford and Orange counties have 99% and 95%, respectively.

Maps of the various combinations of sheet erosion and gullying have been made, but there is not space here to reproduce all of them. Three may, however, be briefly described. The counties with the largest percentages of their areas damaged by moderate sheet erosion and occasional gullies, with the percentage of their area thus affected are Brown 66, Orange 65, Clark 55, Morgan 54, Gibson 50, Jefferson 49, Knox 45, Henry 41, Warren 40, Fayette and Wayne 39, Clay 35, Decatur and Monroe 34, Sullivan 33, Union and Tippecanoe 32, Grant 31, and Jennings and Delaware 28. Most of these high counties are in the southwestern third of the state. The largest area with little erosion of this particular type is in the northwestern part of the state and the next largest is in the center of the state.

Moderate sheet erosion is accompanied with frequent gullies in much of the southwestern part of the state, where some 12 counties extending from Parke to Floyd and Warrick have 30% or more of their areas of this type and four counties have more than half of their areas thus classified. By contrast, only three counties to the north or east of a line from Jefferson to Fountain counties have as much as 1% of their land in this category. They are Porter 40, Steuben 7, Cass 5, and Huntington 3.

Severe sheet erosion and occasional gullies damage most land at the extreme southeast, where four counties have over half of their land in this category, namely, Ohio 76, Dearborn 73, Switzerland 69, and Franklin 58. Nearby counties also rank relatively high, Fayette 21, Union 10, Wayne 11, Ripley 4, and Rush 2. In no other part of the state is this combination extensive except in Vanderburg County 21%, Lawrence 5, Harrison 4, Washington 3, and Morgan and Johnson 2. None of the counties of the northern half of the state have as much as 1% of this type.

The final map of erosion is that showing the most serious combination, that of numerous or frequent gullies and severe sheet erosion. In this type, less than one-fourth of the original thickness of the topsoil remains, and in many places the topsoil is all gone. Likewise gullies are numerous, a considerable number of them cutting well into the subsoil, or even down to the bed-rock. This most extreme type of widespread erosion in Indiana is dealt with in Figure 10. It is largely confined to the southern third of the state and affects the largest percentage of the land in the counties extending from Brown to Pike, which have from 20 to 52% of their land of this category. Various nearby counties also rank high. North of the line marked O in Figure 10, there are, however,

only nine counties, with appreciable representation of this type, severe sheet erosion and frequent gullies. They, with the percents of their areas, are Wayne 5, Steuben and Laporte 3, Porter and Lagrange 2, Noble and Henry 1, and Parke and Elkhart with less than 1%.

A Summary for Erosion. A brief summary of the results of the above analysis of soil erosion in Indiana is desirable before considering the probable explanations of the regional contrasts disclosed.

Except for wind erosion which is most extensive in the northwest, erosion is most extensive in the southern part of the state. Indeed much of the central and north-central part of the state has little serious erosion. In the extreme northern and northwestern counties, moderate sheet erosion without gullying is, to be sure, rather extensive in the rougher counties. Nevertheless, severe sheet erosion is largely confined to the counties near the Ohio River. In general, gullying likewise increases in severity southward, although it is by no means lacking on the steeper slopes in the north. Gullies are most numerous, on the average, in the south-central and southwestern parts of the state, although on some of the almost flat land near the rivers they are not numerous.

The combination of considerable (moderate or severe) sheet erosion with considerable gullying (occasional or numerous gullies), dealt with in Figure 9, shows quite clearly the general southward increase shown by most of the maps. But this combination is of such significance that it has been analyzed in a special way. The counties north of latitude 41° have on the average about one-eighth of their area subject to considerable erosion of these types. The belt between the 40th and the 41st parallels (22 counties) have an average of about one-sixth of their area of this category. The 25 counties between the 39th and the 40th parallels have an average of 43% of their areas in this same category. The 24 counties south of the 39th parallel have, on the other hand, an average of 66% of their areas in this category.

Some Possible Explanations of the Regional Contrasts in Erosion

Why this southward increase? Why the greater erosion in the central section of southern Indiana than on either side? Why the more intense erosion at the extreme southeast corner? Why more gullying at the southwest than in the southeast or even in the south-central section?

The regional contrasts in soil erosion must necessarily correlate with variations in the effectiveness of the agencies of erosion, which here are the wind and running water, and with the availability of soil materials that can be carried away by these agents. The effectiveness of the wind varies with its strength, with the dryness and looseness of the soil, and with the protection afforded by vegetation or other barriers to wind movement. In Indiana, wind erosion is largely confined to the sandier soils, which are the only ones that normally are loose when dry. The loams and clays commonly are quite hard when dry. Even when pulverized by cultivation, clays and loams very seldom remain loose on top for more than a short time in Indiana. This is because showers are frequent enough here, especially in spring when most cultivation is done, soon to form a crust on top of the loosened layer of clay or loam. Sand,

however, lacks the stickiness required to form such a crust, and soon after a shower it may be loose enough to be moved by the wind. The sandy soils in all parts of the state are not equally eroded by the wind. Sandy soils in southern Indiana, in Jackson and Gibson counties, for example, are eroded less than are similar soils in the northwest, partly because they are less dry in winter. The northwestern corner of the state receives less precipitation in the winter than any other part, less than two-thirds as much as southern Indiana, and also has the strongest winds then. These conditions are highly favorable to wind erosion, as are the extensive sandy areas, the small interference from trees or hills, and the extensive corn fields, many of which are rather barren in winter.

Most erosion in Indiana is accomplished by the run-off of rain. The greater the run-off, the greater the potential erosion, both because of the greater volume of water to do the work, and especially because of the greatly increased velocity that the run-off attains as the amount increases. When there is little run-off, the friction with the surface and small obstacles normally permits only a slow flow, which means little transporting power and hence little erosion.

The amount of run-off varies with six main factors: the amount of rainfall, its intensity or rate of fall, the slope, the amount of absorption by the soil and associated materials, the evaporation, and the vegetal cover. The slope includes not only the larger features, but also the lesser irregularities and the presence of channels. The amount of absorption depends upon the porosity of the soil itself, the openings in the soil, such as root cavities and the burrows of animals, and, especially, the degree of saturation. Even a sand, which can absorb one-fourth of its weight of water when dry, cannot absorb much water if its upper layers are already saturated.

Annual and seasonal rainfall: In Indiana the amount of rainfall varies for the annual average from slightly less than 35 inches at the north to about 45 inches at the south. Hence, if all other factors were equal, the amount of erosion should be approximately one-third greater at the south than in the north. But instead of being one-third greater, it is several times as great! (A map of the annual precipitation is given in the *Proceedings* for last year, Fig. 20, p. 193.)

The rainfall during the four warmer months, June to September, inclusive, causes far less erosion on the average than do similar amounts during the cooler months. This is because in the summer the soil is commonly dry enough to absorb a considerable share or all of the rainfall if it does not fall with too great intensity. Moreover, evaporation is relatively rapid, soon removing a part of the water. Furthermore, the soil is more porous in summer than during the rest of the year because of the greater activity of burrowing animals and man (cultivation). Finally, of especial importance, vegetal protection normally is greatest in those months.

Hence, the regional contrasts in the amount of rainfall during the cooler months is much more significant as far as erosion is concerned than is the annual total. In Indiana all parts receive about the same amounts of rainfall during the summer, and, as a result, the contrast in winter is notably greater than for the year as a whole. During the

eight cooler months the totals in the north average about 21 inches, in the center about 25 and at the south about 30 inches. Figure 11 shows the "standard" precipitation totals for these months for the various parts of the state. (The "standard data" are the figures for the 35-year period 1898-1932 and are more strictly comparable than are the averages of all data.) This map reveals that southern Indiana receives nearly a half more precipitation during the cooler months than does the north. Indeed, several stations in south-central Indiana receive approximately 32 inches of rain in these months, which is 60% more than the total for three northwestern and two northeastern stations.

During the three winter months, the contrast is even greater, because of the scanty precipitation received then at the north. In the three winter months, the southern counties receive nearly twice as much precipitation as does the north, and Crawford County and vicinity more than twice as much as the northwestern or northeastern corners of the state. (A map of the winter precipitation forms Fig. 26, p. 198, of last year's *Proceedings*.)

Hence, the regional contrasts in the amounts of rainfall received annually, and especially during the cooler months, help explain the regional contrasts in erosion. But the erosional contrasts are much greater than the contrasts in mere annual or seasonal rainfall, and, hence, other factors merit consideration.

Glacial Contrasts and Erosion. Southern Indiana differs from northern Indiana with respect to glaciation. Figure 12 is a glacial map, simplified from Malott's map (1922), which in turn was based on Lever-

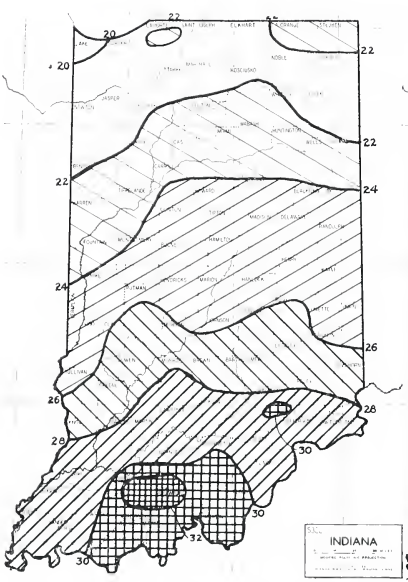

Fig. 11. Percipitation during the eight cooler months, October to May inclusive, in inches.

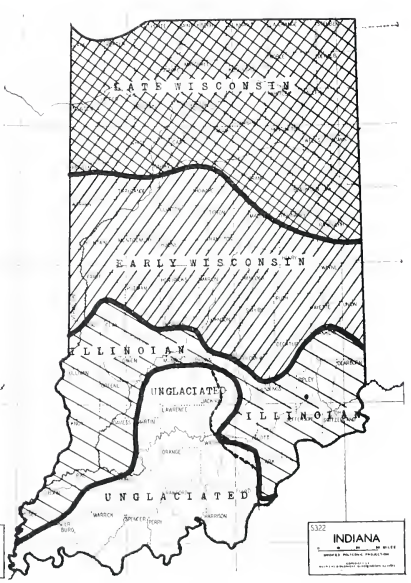

Fig. 12. Glaciation areas (after Leverett and Malott).

ett's map (1914).[1] When this map is compared with the erosion maps, it is apparent that there are general correlations between glaciation and erosion. Thus, the unglaciated area has in general more erosion than the glaciated, and the areas covered by the older, Illinoian glacier, have more erosion than the section covered by the Wisconsin ice sheet. Similarly the area covered by the Late Wisconsin advance has, on the average, less water erosion than does the Early Wisconsin drift sheet. Such contrasts are to be expected, as erosion requires time, and sufficient time has not yet elapsed since the Late Wisconsin to drain adequately many parts of northern Indiana. Run-off erosion is necessarily slow when there are no appreciable slopes or channels. On the other hand, the region covered only by the Illinois ice sheet has been rather thoroughly drained and reduced to slopes. Most of the unglaciated area is rather hilly.

The contrasts in glaciation are, however, inadequate to explain nearly all the contrasts in soil erosion. Moreover, the question as to what caused the glaciers to terminate where they did is a proper one to raise in this connection. Quite probably their extent is merely a reflection of more fundamental conditions which affect erosion independently.

The inadequacy of the distribution of glaciation to explain the contrasts in erosion may be briefly illustrated. Although both the southeastern and southwestern parts of the state were covered by the Illinoian ice sheet, they differ quite decidedly in erosion; the percentages of the areas with severe sheet erosion are greater at the east, while gullying is more widespread and severe at the west. Likewise, although the unglaciated area has more erosion on the average than the Illinoian area, nevertheless parts of the latter are about as unfortunate. Moreover, parts of the unglaciated area are classed as subject to little or no erosion, while certain areas of even the Late Wisconsin drift sheet are rather badly eroded.

Slope: Another factor of major significance, unquestionably, is the amount of slope of the land. Figures 13 and 14 deal with local relief in two ways. Figure 13 deals with the maximum local differences in elevation for each county, while Figure 14 classifies the various parts of the state into four categories of ruggedness. The data upon which both these maps were based are rather unsatisfactory, as topographic maps of only a small portion of Indiana have been made. Figure 13 is based on data compiled by Malott in his chapter on Physiography in the *Handbook of Indiana Geology*, 1922. Figure 14 is based on miscellaneous field impressions. The part of the state shown as cross shaded is, in general, rather hilly; the area which is shaded most lightly is, in general, level or almost level. The other two types are intermediate, the darker one the rougher.

Local relief clearly helps explain some of the erosional contrasts, such as a part of the considerable contrast between the southeastern and

[1]In the area here labelled as unglaciated, that part east of the dashed line is not entirely lacking in glacial deposits, although most of it is rugged upland, resembling the unglaciated area to the west rather than the more strongly glaciated area to the east. See W. D. Thornbury, Notes on the glacial boundary in southern Indiana. Proceed. Ind. Acad. Sci. 41:351-354, 1932.

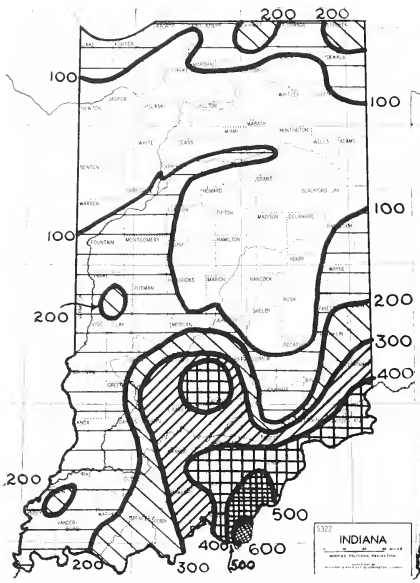

Fig. 13. Contrasts in maximum local relief, by counties.

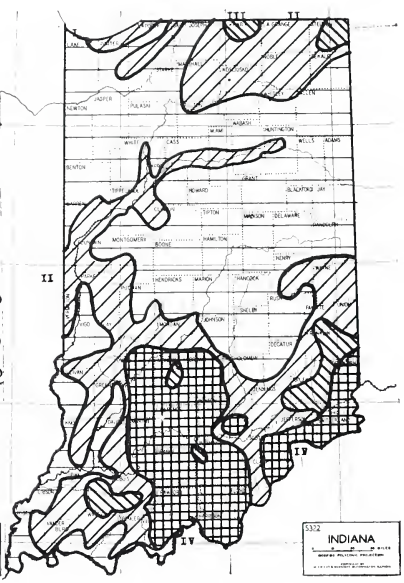

Fig. 14. Regions as to ruggedness. The crossed areas are prevailingly hilly; those with the lightest shading are prevailingly almost level.

the southwestern corners of the state, both covered by the Illinoian ice sheet, but now differing markedly in local relief. The greater local relief also helps to explain the presence of extensive erosion in the area from Parke to Owen County although it was covered by the Illinoian ice sheet. Likewise the greater erosion in some of the most northern counties, especially at the northeast, as compared with adjacent counties to the south, is obviously related to their greater relief, due to terminal moraines.

The relief features of Indiana are of four main sorts: those due to the irregularities of glacial deposition (over much of the northern half of the state); those due to wind work (the sand dunes near Lake Michigan); those due to solution (the sinkhole topography of part of the unglaciated region); and, finally, those due to run-off. The topographic irregularities due to run-off erosion doubtless checked glacial advance. Two other influences interfering with the extension of glaciation were elevation and unfavorable climate. The northeastern part of the unglaciated area is relatively elevated (a map showing elevations may be found in Proceedings for last year, Fig. 2, p. 185). These areas are less elevated, however, than is an extensive glaciated area nearby. Moreover, a considerable southwestern part of the unglaciated area is the least elevated part of the state, or only a little higher. Hence climatic conditions and local relief seem to have been more important than local elevation in determining the termination of the glacial advance. (Distant differences of elevation helped in the development of glacial lobes, which were a great factor in determining the relative advance of the ice-front.)

It has commonly been assumed that the aspect of the climate which was of overwhelming significance in stopping glacial advance was the temperature. Southern Indiana has, to be sure, higher average temperatures than central or northern Indiana, but the differences are slight during the summer months. Indeed, continental interiors generally warm up in summer so greatly that the decline in temperature with increased latitude is relatively small.

A climatic factor of great significance in melting the ice is rainfall. If rainfall is abundant in the winter as well as in the summer the glacier advances with greater difficulty if at all. Moreover, abundant cool season rain is, as already remarked, especially effective in causing run-off erosion, and, hence, in making the topography rugged, which ruggedness likewise interferes seriously with glacial advance.

The much greater rainfall during the cooler months in southern Indiana than in northern has already been mentioned and mapped (Fig. 11). Here, however, attention may advantageously be devoted for a time to the regional contrasts in rainfall intensity.

Rainfall Intensity and Erosion: Figures 15 to 20 deal with various aspects of rainfall intensity. Figure 15 shows the frequency of months during which a total rainfall of ten inches or more falls during the month. It reveals that such a large monthly rain occurs at least once a year in more than one-tenth of the cooler half-years at the southwest but almost never in most of the northern part of the state. The area where erosion is most intense (Fig. 10) roughly coincides with the area that has ten inches of monthly rainfall most frequently.

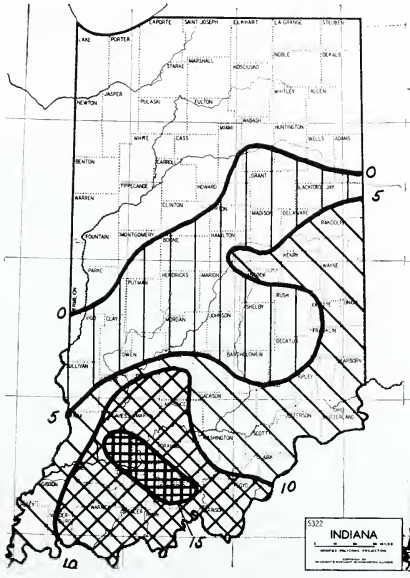

Fig. 15. Ten inches of rain in a month. Percentage of the cooler half years having such a monthly total.

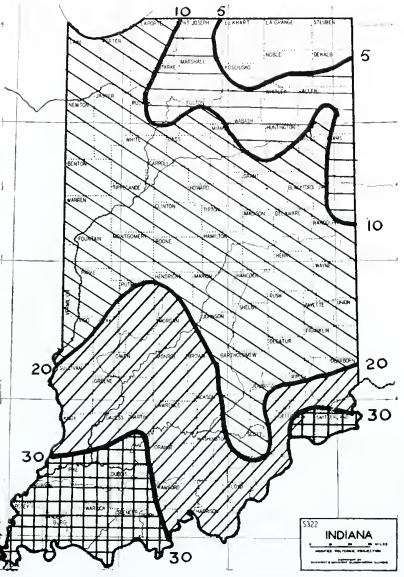

Fig. 16. Two-day rains of six inches or more. Percentage of years with such.

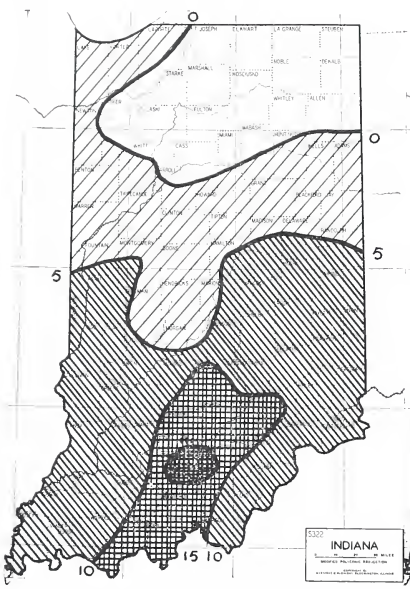

Fig 17. Four-day rains of six inches or more. Percentage of years with such.

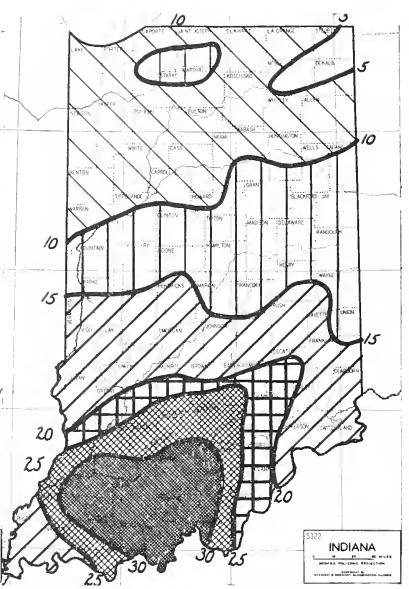

Fig. 18. Daily rains of one inch or more, in winter. Times per decade.

Figure 16 concerns the frequency of two-day rains of four inches or more. It indicates that the southwestern corner of the state receives four inches of rain during two consecutive days at least once a year in more than 30% of the years. By contrast, such rains occur less than one-sixth as often at the opposite corner of the state.

Figure 17 deals with even greater rainfall totals, those of six inches or more falling within four consecutive days. Such a prolonged heavy rain necessarily results in much run-off and extensive erosion if other conditions are favorable for erosion. This map shows that in south-central Indiana from 10 to 15% of the years have such rains, while a large area in the north has scarcely ever experienced such rainfalls.

Figure 18 deals with a much more common type of rain, daily rains of one inch or more. It shows that during the three winter months such rains are received in the southwest-central part of the state more than three times an average winter. On the other hand such rains are less than one-third as common in most of northern Indiana, and less than one-sixth as common in northeastern Indiana.

Figure 19 deals with the frequency of two-day rains of two inches or more in winter. A large share of such rainfall must necessarily run away as the ground normally is saturated by the first inch of winter rainfall, if not before. This map shows that two-day rains are several to many times as frequent in southern Indiana in winter as in most of northern Indiana. Indeed, in about one-sixth of the state, in the north, such rains occur less than once a decade on the average, in contrast with more than ten times at the southwest.

Consideration has now been given to annual, seasonal, and monthly rainfalls, and to the rainfalls during one day, two days, and four days. Another type of rainfall which is highly significant so far as soil erosion is concerned, is the "short rain of excessive amount." When an inch of rain falls during one hour, or an inch and a half within two hours, for example, the run-off normally is great from sloping land as there is not time enough for much rain to soak into the ground. Such rains during the cooler season are especially conducive to soil erosion because the soil normally is already fairly well saturated before the deluge commences. Figure 20 shows that excessive short rains are almost unknown in winter in northern Indiana but occur in about one-fourth of the winters in the southwest. (The figures are times per 30 years.)

The striking regional contrasts in rainfall intensity that occur in Indiana, illustrated by Figures 15 to 20,[2] clearly are helpful in explaining the observed regional contrasts in erosion. Since these contrasts are largely due to fundamental conditions, it is altogether probable that similar contrasts existed during the glacial period and before. (Regional contrasts in the duration of snow-covered and of frozen ground also help explain the relatively greater erosion in southern than in northern Indiana. These influences and others are discussed in a more technical paper.)

In addition to the broad regional contrasts in soil erosion discussed above, there are many local contrasts associated with differences in soil, vegetation and farm practices. Some of them have regional aspects.

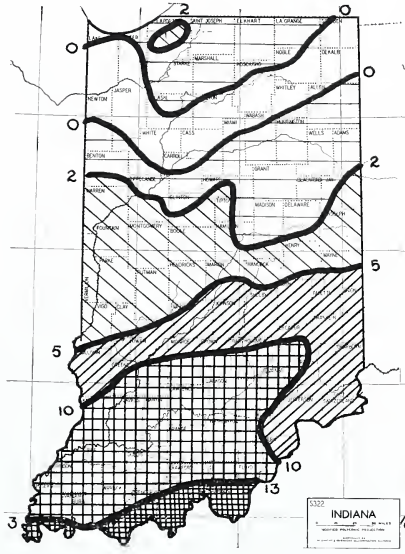

Fig. 19. Two day rains of two inches or more, in winter. Times per decade.

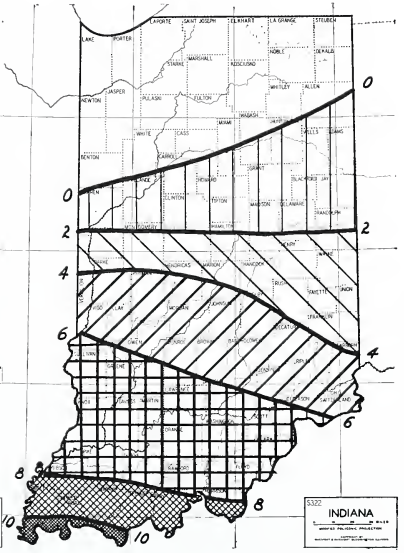

Fig. 20. Number of excessive "short rains" (one inch per hour or 1.5 inches in two hours) per thirty winters.

[2]Figure 20 is based on all the available records at five regular weather bureau stations in Indiana, supplemented by the data gathered by five nearby regular stations, Chicago, Louisville, Cincinnati, Dayton, and Peoria. Figures 11, 15, 16, and 17 are based on all the available data accumulated from eighty Indiana stations. Figures 18 and 19 are based on the daily records for one recent decade for all Indiana's stations.

For example, since southern Indiana was settled before northern Indiana, clearing was done sooner, and soil erosion of tilled land commenced earlier. During the past 40 years, however, many of the steeper slopes in southern Indiana have been abandoned because so much of their soil had been removed during the period of cultivation. (In some parts of southern Indiana, certain hillsides are classed as "ten-year land" because during ten years of tillage by the customary methods so much of the soil washes away that further tillage is unprofitable.) As a result of the abandonment, some time ago, of many areas in southern Indiana, the average period of cultivation in southern Indiana is perhaps no longer than that of northern Indiana despite the fact that much of northern half of the state was not cleared until two or three decades after the south was well settled.

The large proportion of the more rugged parts of southern Indiana that are now covered with brush or trees led to an interesting and significant "inaccuracy" in the soil erosion map. Since wooded areas lose soil by erosion only slowly, wooded tracts are classed as subject to little erosion if they are not gullied. If they are gullied, they are generally classed as subject to moderate erosion. If wooded tracts make up more than 75% of the land of any square mile, the surveyors were required by their instructions to report the land as subject to little or moderate erosion, even if rapid erosion prevailed on the small percentage of cultivated land. (Several southern counties had at the 1935 agricultural census only relatively small percentages of their areas in harvested crops. Examples, with the percentages are: Brown 10, Crawford, Martin and Monroe 19, Perry 20, Lawrence and Orange 22, Harrison 23, Washington and Scott 24, Jefferson 26. The state average is 44, with Benton County 68. As a result of these instructions as to how to classify the land, the soil erosion map analyzed in Figures 2-10 underestimates the regional contrasts in erosion.

Conclusions

There are marked regional contrasts in soil erosion in Indiana. Upon moderate slopes on comparable soils, erosion is several times as rapid at the south as at the north; upon steep slopes, the differences are even greater. These contrasts are associated with contrasts in rainfall since run-off is the one great cause of soil erosion in Indiana, except on some very sandy tracts especially in the northwest where wind erosion is significant. The one-third greater annual rainfall which the south receives helps to explain the contrasts in erosion, but the fact that the south receives nearly one-half more rainfall during the cooler eight months than does the north is even more significant, as a larger percentage of cool-weather rain runs away. Differences in the length of time since the glaciers covered the various parts of the state are also of significance, as the development of drainage run-off courses and related slopes required much time when the state was forested, as it nearly all was until about a century ago. The amount of local relief, a special phase of the slope, is of further assistance in causing the observed regional contrasts in soil erosion. A climatic factor not previously investigated, namely regional contrasts in rainfall intensity, is

also clearly of great importance in causing the large regional contrasts. Southern Indiana has several to many times as many downpours and consecutive days of heavy rain, as does northern Indiana. Such rains yield much mode run-off than do moderate ones, and since the transporting power of run-off increases approximately as the cube of the velocity, erosion increases enormously where heavy rains occur relatively frequently, provided the soil is not protected by adequate vegetal cover. The evidence presented here should hasten the program of reforestation of all the steeper slopes in southern Indiana.

Epilogue.—The considerable amount of soil loss that has resulted in Indiana in only a century or less from the cultivation of sloping lands makes very desirable certain changes in the use of such lands. The demonstrations conducted by the Soil Conservation Service in Lawrence and Henry counties and elsewhere show methods by which moderate slopes can be farmed with much less soil wastage than has occurred with the prevailing practices. These demonstrations and others have also disclosed approximately what amount of slope, on different soils, can safely be tilled without special technique, what sorts require various special methods, what slopes should be kept in grass or trees, and what slopes are too steep for even pastures but should be forested.

The rapid destruction of the land by erosion in Indiana, except on very gentle slopes, adds clear evidence of the need of extensive withdrawal of such land from cultivation. Already a large share of the sloping lands of southern Indiana have, indeed, been almost irreparably damaged by erosion. Since hillsides in Indiana are well adapted for forest growth, if they have enough soil, and since there will soon be an urgent national need for more lumber, extensive reforestation should be strongly encouraged on the sloping lands of Indiana. Indeed in southern Indiana, at least, only the almost level land should, ideally, be tilled.

In 1921 a law was passed by the legislature providing for the virtual exemption from taxation of land officially classified as forest land, and not pastured. This was a step in the right direction, but it was quite inadequate as far as checking soil wastage is concerned, because little land has been so classified, and a large proportion of that little is flat land not subject to erosion.

A law exempting from taxation all wooded land on hillsides, whether pastured or not, doubtless would lead to a substantially increased use of hillsides for grass and trees, and hence to a real reduction in erosion. It would also be desirable to tax at a reduced rate hillside grass land, even if not yet wooded. If hillsides that are tilled were taxed double the rate used for almost level fields, soil wastage would be rather effectively reduced! Such excess taxation is justified partly because rapid soil removal results in injury to other lands, roads, and streams. (It is comparable to the heavy taxes on dogs because some dogs kill sheep. Sheep killed by dogs are paid for out of the dog tax. Similarly, under the proposed hillside tax, the tax paid by the landowner who farmed hillsides would be partly used to relieve the tax burden of the man who used his hillsides in such a way as to conserve the soil).