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Soil Erosion in Iowa

SOILS SUBSECTION, IOWA AGRICULTURAL EXPERIMENT STATION AND SOIL CONSERVATION SERVICE, U. S. D. A. COOPERATING

APRIL, 1936 SPECIAL REPORT No. 2

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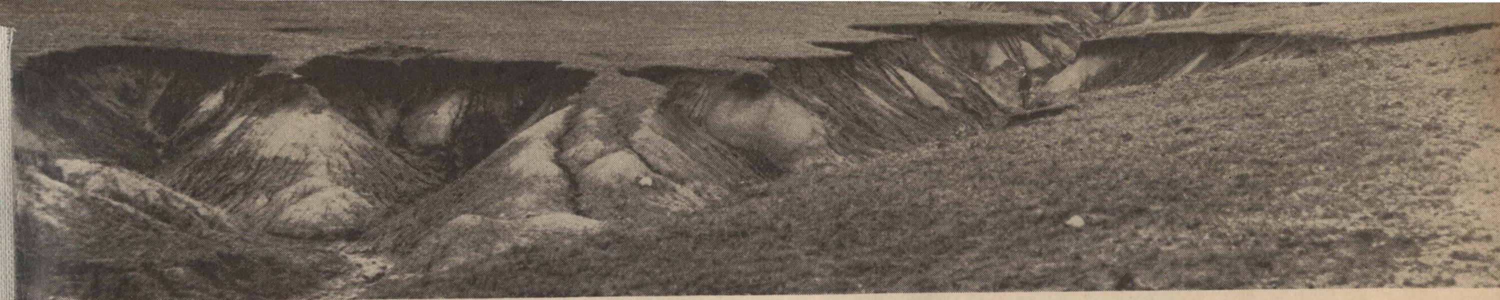

April, 1936

Special Report No. 2

Soil Erosion in Iowa

By R. H. Walker and P. E. Brown

SOILS SUBSECTION
Agricultural Experiment Station
Iowa State College of Agriculture
and Mechanic Arts
R. E. BUCHANAN, Director
and
SOIL CONSERVATION SERVICE
United States Department of Agriculture
Cooperating

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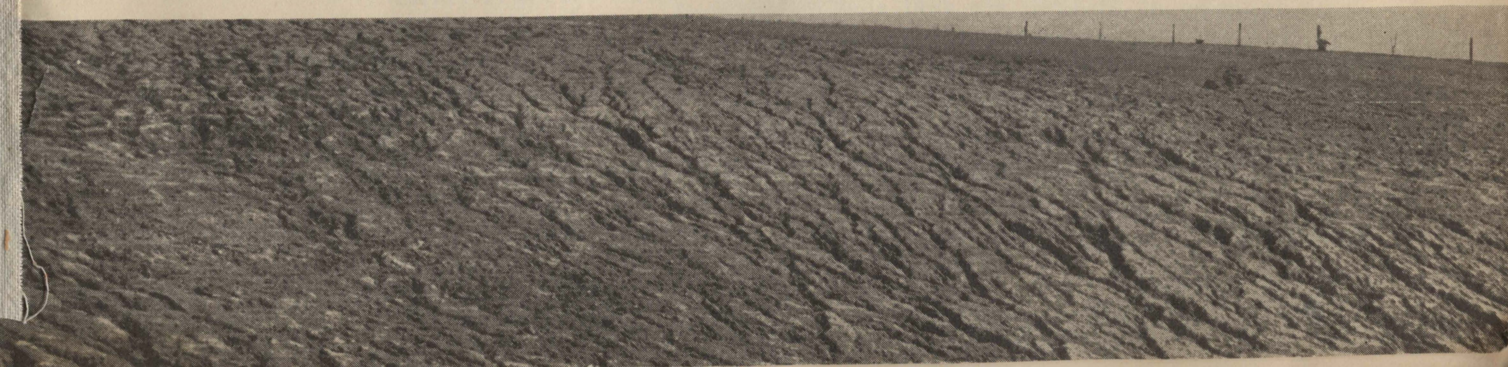

Contents

Summary

1. In the late summer of 1934 the Soil Conservation Service began a reconnaissance erosion survey of the United States. The Soils Subsection of the Iowa Agricultural Experiment Station cooperated in Iowa, and the findings are reported in this bulletin.

2. In the Iowa survey observations were made on: (1) The factors influencing soil erosion; (2) the extent and seriousness of erosion in the various parts of the state, and (3) control measures which have been found to combat soil erosion successfully.

3. The factors influencing soil erosion in Iowa are: (1) The amount, distribution and intensity of the rainfall; (2) the topography of the land, which includes the degree of slope, the length of the slopes and the total area of the slopes of the drainageways; (3) the erodibility of the particular soil type or the summation of the combined physical and chemical characteristics of the soil which may allow it to erode; and (4) the soil management practices and especially the type of vegetative cover.

4. The survey revealed: (1) That only about 13 percent of the total land area of Iowa shows little or no evidence of erosion; (2) that approximately a third of the land shows slight sheet erosion, and up to 25 percent of the original surface soil has been washed away; (3) that more than 14 percent of the land has lost 25 to 50 percent of its surface soil by erosion and that most of this area shows occasional to moderate gullying; (4) that about 31 percent of the land has been seriously eroded and 50 to 75 percent of the original, fertile, surface soil has been washed away, and that this land has also been moderately to excessively gullied; and (5) that about 9 percent of the land has been severely eroded and has had 75 percent or more of the original surface soil washed away by erosion and that there has also been moderate to excessive gullying in this area.

5. Approximately 30 billion tons of soil have been estimated to have been washed away from Iowa land since its cultivation was begun by man. This is equivalent to a loss of more than 137,000 tons of soil per 160-acre farm or approximately 35 percent of the original surface soil. It is obvious that a much greater percentage of the surface soil than this has been lost in those areas of the state where erosion has been most severe.

6. Along with the loss of surface soil there has been a tremendous loss of plant nutrients amounting to about 247 tons of nitrogen, 82 tons of phosphorus and 2,046 tons of potassium for every 160 acres. On the basis of the present price of commercial fertilizers containing these plant nutrients this loss would amount to approximately $2,975 per acre of farm land. The capital value of Iowa farms, thus, is being depleted by erosion—a depletion that is actually far greater in value than the land's market price.

7. Erosion is in the incipient stage on much Iowa land and the evidences of it are not readily recognized. Unless serious consideration is given to prevention there will undoubtedly be a rapid increase in erosion on this land. In time these areas will be affected to the same extent as those lands that are now rapidly approaching ruin.

8. Undoubtedly nature has demonstrated the ideal method of controlling soil erosion by maintaining grass on the rolling prairie lands, and grass, brush and timber on the rougher lands bordering the streams. This method may well be set up as an ideal when planning soil management practices for the best results.

9. To control soil erosion in farm practice it would be wise to grow non-tilled and pasture crops at regular and frequent intervals, reforest steep and broken areas, and build up the organic matter content of the soil. To do these things and at the same time produce the necessary inter-tilled crops, it is essential: (1) To cultivate the soil properly and adapt the cultivation practices to the land according to the needs for erosion control, in many cases including contour planting and cultivation of the crop, terracing and other special cultivation measures; (2) to follow a well planned crop rotation adapted to the soil type; (3) to apply limestone to acid soils so that legume crops may be grown in the rotation; (4) to plow under crop residues, green manure crops and farm manure to increase the organic matter content of the soil which in turn increases its water-absorptive and water-holding capacity and decreases its erodibility; and (5) to fertilize soils that are deficient in essential plant nutrients in order that a greater abundance of vegetative cover may be provided which in turn markedly decreases the erosive action of run-off water. These practices make up the essentials of the Iowa system of soil management.

Foreword

THE reconnaissance erosion survey of Iowa reported here was conducted in the late summer of 1934, as a part of a national survey made by the Soil Conservation Service of the United States Department of Agriculture.[1] The survey was made under the immediate supervision of R. E. Uhland, regional director, and William DeYoung, chief soils specialist, for the Soil Conservation Service at Bethany, Mo. The field work was done by M. H. Brown, O. R. Neal, G. W. Musgrave and R. E. Bennett of the Soil Conservation Service, and A. J. Englehorn and R. H. Walker of the Iowa Agricultural Experiment Station.

The data and maps showing the extent of erosion classes, slope classes, and depth of surface soil were prepared by M. H. Brown of the Soil Conservation Service. The soil area and soil type maps were prepared by B. J. Firkins of the Department of Agronomy at Iowa State College. The pasture map was furnished by the Iowa State Planning Board. The census data used in preparing the inter-tilled and non-tilled crop maps were supplied by the Agricultural Economics Subsection at Iowa State College. The data concerning methods of erosion control, as obtained at the Soil Erosion Experiment Stations near Clarinda in Page County, Iowa, and at Bethany, Mo., were furnished by G. W. Musgrave and R. E. Uhland. The pictures were kindly furnished by the Soil Conservation Service at Bethany, Mo., and at Shenandoah, Iowa. Various members of the Soil Conservation Service and of the Department of Agronomy at Iowa State College have also offered valuable suggestions and criticisms and have aided materially in this work.

To all those who have aided in the completion of the erosion reconnaissance survey and in the preparation of this bulletin the authors are deeply indebted and take this opportunity to express appreciation.

[1]At the time the reconnaissance erosion survey was made the Soil Conservation Service was known as the Soil Erosion Service, and it was administered under the United States Department of the Interior. At that time also G. W. Musgrave, superintendent of the Soil Erosion Experiment Stations at Clarinda, Iowa, and Bethany, Mo., was on the staff of the Bureau of Chemistry and Soils of the United States Department of Agriculture, and R. E. Bennett was on the staff of the Iowa Agricultural Experiment Station.

Soil Erosion in Iowa*

By R. H. Walker and P. E. Brown

WHEN the first settlers came to Iowa they found the land covered with a dense vegetative growth of native grasses on the open prairie, and timber, brush and grasses on the more hilly land bordering the streams. This vegetative cover held the rain and snow and thus prevented the loss of water by runoff except during the heaviest rains. Furthermore, the precipitation was largely and rapidly absorbed by the soils because of their unusually high organic matter content which had been built up by the accumulation of grass roots and leaves through the ages. Even when the runoff did occur, the native vegetation protected the soil from being washed away. Under these virgin conditions, maximum protection was afforded the soil against erosion.

As the land was broken out of the native sod and cultivated, native vegetative cover was destroyed and soil erosion begun. Nature's chief defense against this destructive action was broken down. Inter-tilled crops such as corn were grown, and the soil was left bare and exposed to erosion during the spring and early summer months when the rainfall is normally high. Steep hillsides that should have been left in native prairie sod or cropped to thick-growing hay or grain crops were planted to corn and other inter-tilled crops which were cultivated up and down the slopes. The furrows left between corn rows served as channels for the collection and runoff of excess rain, and these frequently developed into small gullies during single rains. In these water channels enormous amounts of the surface soil were carried away from much of the rolling land.

As the land was more intensively cropped without regard to the maintenance of fertility, the organic matter content gradually decreased, and, as a result, the water absorptive capacity was reduced. This increased the runoff water, which carried away more and more soil, and the soil-cutting and transporting power of the water was increased. Furthermore, as the land became less and less productive owing to the loss of the fertile top-soil by erosion, new land was broken up, and this was generally the steeper hillsides. It consequently was not only less valuable for crop production but also subject to more rapid erosion. Thus the erosion situation became rapidly worse from year to year.

Because the washing away of the soil occurred rather slowly at first, it went on practically unnoticed. Large amounts of fertile surface soil were washed away before gullies appeared, and even then little attention was given to them, because they developed slowly and without much apparent damage. As time went on, however, erosion increased at an alarming rate and practically ruined much of the land on many Iowa farms.

Some farmers have sensed the seriousness of erosion and have made an effort to prevent it, but they have been handicapped because the factors that promoted erosion and the methods of control were not clearly understood. Most farmers, however, have had no idea of the enormous wastage of fertile surface soil, and they have allowed this waste to go on unchecked. As a result parts of many farms are now unfit for growing cultivated crops, and extensive areas of once fertile land are fast approaching that condition. Many Iowa farmers are facing the possibility of complete loss of their land, which is their capital investment. And there is no possibility of recovering the soil when it is once lost except by those exceedingly slow natural processes of soil building that require many centuries to develop a comparatively thin layer of surface soil.

To prevent the continuance of erosion it is necessary that there be immediate action by the individual farmer, as well as by those governmental agencies that have been organized to demonstrate methods for soil conservation.

THE PURPOSE OF THE RECONNAISSANCE SOIL EROSION SURVEY IN IOWA

The Soil Conservation Service of the United States Department of Agriculture was organized to develop a coordinated attack upon erosion on agricultural lands in cooperation with farmers. Some of the first problems of this organization were to determine: (1) In what areas soil erosion occurs, and (2) the character and seriousness of erosion in the different soils of the country. It was to solve these problems that the Soil Conservation Service, in cooperation with the Agricultural Ex-

*Project No. 492 of the Iowa Agricultural Experiment Station.

periment Station, made a reconnaissance erosion survey of Iowa, which is reported in this bulletin.

METHODS USED IN MAKING THE EROSION SURVEY

In making the reconnaissance soil erosion survey of Iowa, each county was surveyed as a unit. Soil survey maps were used as base maps for the counties that had been surveyed, and for counties where soil survey maps were not available, county engineers' maps or county highway road maps were used. Two persons drove from 100 to 150 miles over selected roads in each county. An attempt was made to go over each county somewhat systematically, and when possible to drive at right angles to the general directions of the streams and natural drainage in the county. Special attention was given to those areas in each county that were most likely to be subject to soil erosion as indicated by the soil and other maps showing the general topography and character of the land.

While driving over the area observations were made of: (1) The general topography of the land in terms of the average degree of slope; (2) the character of the soils and the extent and seriousness of sheet erosion; (3) the character and extent of gully formation; (4) the general soil management practices followed that tend to increase or control soil erosion. In addition to the actual survey conducted in the field, the data included in the state assessors' reports were studied to determine the acreages of the various crops grown and the percentages of the land utilized to produce crops that tend to promote or prevent erosion.

From a topographic standpoint the various erosion areas were grouped as follows: (1) Comparatively *level to gently undulating soils* having slopes ranging from 0 to 5 percent; (2) *gently rolling to rolling soils* having slopes ranging from 5 to 10 percent; (3) *strongly rolling to steep soils* with slopes of 10 to 15 percent; and (4) *steep to rough broken land* having slopes over 15 percent.

The various areas of the state were differentiated on the basis of sheet erosion into the following groups: (1) *Slight sheet erosion* with less than 25 percent of the original surface soil washed away; (2) *moderate sheet erosion,* from 25 to 50 percent of the original surface soil washed away; (3) *serious sheet erosion,* with from 50 to 75 percent of the original surface soil lost by erosion; and (4) *severe sheet erosion* with 75 percent or more of the original surface soil washed away and where in many cases the subsoil is now being carried away.

Three classes of gullying were recognized, namely: (1) *Occasional to moderate gullying* where the size and frequency of the gullies are not so great that it is beyond the power of the individual farmer to combat them successfully; (2) *serious gullying* where a particular area is cut up into a large number of gullies and where their control is a difficult problem when the soil is cultivated; (3) *excessive gullying* where the gullies are so numerous and of such a character as to make the land unfit for cultivation.

The term *sheet erosion* refers to the washing away of the surface soil without gully formation. This is the most prevalent type of soil erosion on cultivated lands, and it is the most injurious. Its progress, although rapid on many soils, is not as noticeable

Fig. 1. A dense vegetative cover of native grasses on the open prairie, and of timber, brush and grasses on the more hilly land bordering the streams provides maximum protection against soil erosion. When these are destroyed nature's chief defense against erosion is broken down.

as is gully erosion, and it may proceed practically unnoticed on many farms. Its effects are revealed by: (1) Light-colored spots throughout the field, exposing the lighter-colored subsoil; (2) decreased crop yields resulting from the infertility and drouthiness of the remaining subsoil; and (3) accentuated difficulties of tillage on most soils because of the more compact and impervious nature of the subsoil and its lack of humus or organic matter.

Gully erosion results from the rapid collection of runoff water in the natural depression where it has strong soil-cutting and transporting power. The result is the development of ditches or gullies that, if left uncontrolled, rapidly develop into very large gullies or ravines. This type of erosion is the most noticeable and the type most people think of when soil erosion is mentioned. On most soils, however, serious gully erosion does not develop until after a large proportion of the original surface soil has been carried away by sheet erosion.

The term "original surface soil" as used in this bulletin refers to the immediate surface layer of soil which in most soils was uniformly darker in color and contained more humus or decaying organic matter than the underlying subsoil. The depth of the original surface soil varies widely in the different soil types and also from place to place on individual soil types. In order to establish a standard against which the depth of the remaining surface soil in cultivated fields could be compared, the depth of the original surface soil was determined for each type by examining the soil in virgin pastures or woodlands. Differences in the depth of the surface soil in cultivated fields and in the virgin areas were used in estimating the extent of sheet erosion.

RESULTS OF THE RECONNAISSANCE SOIL EROSION SURVEY

An attempt was made in this reconnaissance erosion survey to make observations on: (1) The factors influencing soil erosion in Iowa; (2) the extent and seriousness of erosion in the various parts of Iowa; and (3) the control measures taken to combat soil erosion successfully. The results of these observations will be presented and discussed in the order named.

FACTORS INFLUENCING SOIL EROSION IN IOWA

It was observed that the character and seriousness of soil erosion in Iowa are influenced by four principal factors as follows: (1) *The amount, distribution and intensity of the rainfall;* (2) *the topography of the land,* which would include the degree of slope, the length of slopes and the total slope area drained by the individual drainageways; (3) *the erodibility of the particular soil type* which may be looked upon as the summation of the combined physical and chemical characteristics of the soil which may allow it to erode; (4) *the type of soil management* practiced on the soils and especially the vegetative cover.

Influence of Rainfall on Erosion

The total amount of annual precipitation has a direct relationship to the amount of soil that may be washed away by erosion. Inasmuch as it is the rainfall runoff that carries away the soil in suspension it is obvious that, under conditions which are similar in other respects, those regions receiving the most precipitation annually are potentially subject to the most soil erosion. Figure 3 shows the normal annual precipitation for the state.[2] It may be observed that the least rainfall occurs in the extreme northwestern part of the state where the annual precipitation is less than 26 inches. In general, the amount of rainfall increases progressively from northwest to southeast where the annual average is 36 inches (page 9).

The distribution of the rainfall and its intensity are probably of greater importance in influencing soil erosion, however, than the total amount of rainfall. For example, if a large percentage of the annual precipitation fell as snow which melted slowly, allowing a large proportion of the water to be absorbed by the soil, there would not be the danger of soil erosion that there would if most of the precipitation fell as rain during the early spring months when a large proportion of the land is bare and unprotected. Furthermore, there would be less danger of erosion if the rainfall were well distributed throughout the growing season than if it were largely concentrated in 2 or 3 months. The average normal distribution of rainfall in Iowa is shown in fig. 4 (page 10). It may be observed that the largest monthly rainfall is in June, and that considerable precipitation occurs during the spring and early summer months when the land is being prepared for corn and later when the corn land is being cultivated. During these periods when much of the land is bare, it is subject to washing.

Figure 5 shows the normal distribution of rainfall in Iowa during June, the wettest month of the year. During this period rainfall is most abundant

[2]The two rainfall maps in figs. 3 and 5 and the data for the chart in fig. 4 were kindly furnished by Mr. Charles D. Reed of the United States Department of Agriculture, Weather Bureau and the Iowa Weather and Crop Bureau. They are also published in Climatological Data, Iowa Section, Vol. XLIII, No. 1, Jan., 1932.

in western and southern Iowa where erosion is most severe (page 10).

Figures 4 and 5 show clearly that the distribution of rainfall is an important factor in determining the extent of soil erosion. The intensity of the rainfall is likewise important. Experiments have shown that soils of certain characteristics can absorb water at definite rates.

The damaging effects of a rainfall of high intensity were observed on April 3, 1934, at the soil erosion experiment station at Bethany, Mo., where the soil is similar to a large proportion of the rolling land of southern Iowa. On that day 3.03 inches of rain fell at an average of 2.36 inches per hour. On a plot which had grown corn previously and was bare at the time of the rain, the loss of soil was 46 tons per acre, which was nearly as great as the entire loss of 56 tons per acre, caused by the 76 rains that fell on this same plot in 1933.

Fig. 2. A field where extensive sheet erosion has occurred; gullies are rapidly forming.

During this intense rainfall an amount of water was lost in runoff from this plot equivalent to 69 percent of the total rainfall of 1933. Several instances have been recorded by the various weather bureau stations in Iowa when intensive rainfalls of 1 to over 2 inches of rain fell during the period of an hour, and other intensive rains of shorter and longer duration. The excessive runoff of water from the land during rains of this nature is extremely damaging unless the soil is sufficiently well covered with vegetation to reduce the soil-carrying power of the water.

Freezing and thawing also have considerable influence on soil erosion. When the soil is frozen its absorptive capacity for rainwater is extremely low. During the winter and early spring months there frequently occurs a warm rain which may thaw out the soil for a few inches. If a heavy rainfall occurs at that time, however, much of the water runs off the land, and because the surface few inches of soil are not frozen much of it may be carried away by the runoff water. Excessive sheet erosion has been observed, particularly in southern Iowa, as a result of these conditions.

Influence of Topography on Erosion

It has been assumed generally that topography is the most important factor influencing erosion and rainfall runoff. This, however, is not always true. It has been shown that the character of the vegetative cover and of the soil itself usually has a greater influence in determining the amount of erosion. The three factors are intimately related, however, and each has an important influence on erosion.

In the reconnaissance survey an estimate was made of the acreage of land in the various slope classes. The total acreage of land in the various slope classes is recorded in table 1. The detailed data for each county are shown in table 2, and the location and extent of the various slope classes in the state are shown on the map in fig. 6 (page 11).

Some Iowa soils occur in areas where the topography is level to gently undulating and where the prevailing slopes are less than 3 percent. The bottomland soils, the soils of the Webster series, and some of the Muscatine and Grundy soils may be classed in this topographic group. In general these soils have not been eroded appreciably, and the topography undoubtedly has been the principal factor determining the extent of erosion.

On soils that are characterized by a strongly rolling topography, where the slopes are steeper than about 3 to 5 percent, other factors may be of greater importance than the topography in determining the extent of erosion. Nevertheless the degree of slope is of considerable importance on these soils. For example, it has been observed that the density of the runoff or the amount of soil suspended in the runoff increases very rapidly with an increase in the degree of slope of the land. Furthermore, the density of the runoff, at least on certain soils, increases with the length of slope.

In soil erosion experiments conducted at Columbia and at Bethany, Mo.,[3] on the Shelby loam and the Shelby silt loam, soils which occur extensively throughout southern Iowa, it was observed that 61 tons of soil were washed away annually when corn was grown on land having an 8 percent slope. On a similar soil where the slope is only 3.7 percent the annual loss was only 20 tons of soil. When the soil on these two slopes was covered with grass the loss of soil by erosion was about the same in both cases.

These results indicate that when there is no covering of vegetation the slope of the land may be the primary factor governing erosion, whereas, the slope may not be of as much significance when the land has a good vegetative cover. Inasmuch as a large percentage of the land of Iowa is bare for a long period in the spring and early summer while it is being prepared for corn and until the corn makes a fairly large growth, the slope of the land is, under practical conditions, a very important factor in erosion control. Special precautions and erosion control methods must be observed in managing soils of rolling to steep topography.

Influence of Soil Erodibility on Erosion

It was observed in this survey that some soils erode comparatively easily while others under the same conditions of rainfall, topography and vegetation erode very little. This difference in erodibility of soils is due to the differences in their physical and chemical characteristics of which there are a number of more or less importance. The principal ones are the texture, structure and organic matter content.

Soils having coarse textures are more resistant to erosion because generally they permit rain water to penetrate more rapidly, thus reducing the amount of runoff, and also because the individual soil particles are larger and heavier than those in fine textured soils, which makes them less easily suspended and carried away by water.

Soils having practically the same texture may differ markedly in erodibility, primarily because they are characteristically different in structure, or arrangement of the soil particles. Some soils, such as the Marshall silt loam, have a mellow, friable and open-structured surface and subsoil which permits rapid penetration of rain water. This condition tends to decrease the amount of runoff and hence erosion. In other soils, such as the Shelby loam of southern Iowa, which have more compact subsoils and are comparatively impervious to the entrance of water, the amount that may penetrate in a given period of time is limited and the amount of runoff water is increased.

The principal character which affects the erodibility of the soil seems to be the aggregation of the soil particles. Those soils having a characteristic granular or crumb-like structure, where the individual soil particles are naturally gathered together to form larger groups which act as a unit physically, appear to be much more resistant to erosion than soils where the individual particles are not aggregated. The Marshall silt loam of western Iowa and

[3]National Resources Board Report, December 1, 1934, p. 165. U. S. Gov. Printing Office, Washington, D. C.

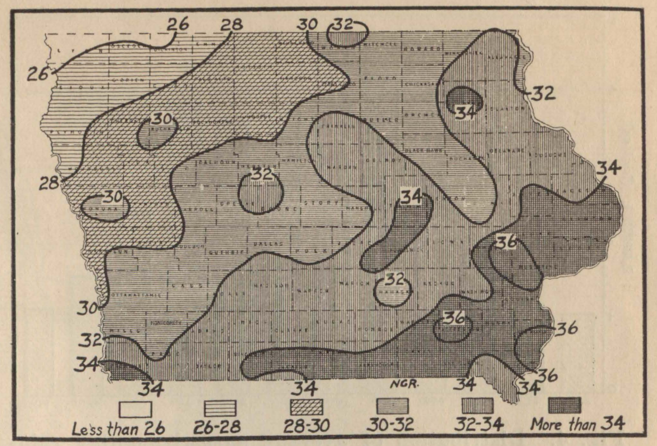

Fig. 3. Normal annual precipitation in inches. State average, 31.89 inches.

TABLE 1. THE ACREAGE AND PERCENTAGE OF SOILS OF DIFFERENT SLOPE CLASSES IN IOWA

Slope classes	Description of slopes	Total acreage in Iowa	Percentage of total land area
Bottom-lands	0 to 3 percent	2,668,800	7.50
A	0 to 3 percent	2,110,720	5.93
H	0 to 5 percent	10,809,600	30.38
HK	0 to 5 percent with some 5 to 10 percent	1,825,280	5.13
K	5 to 10 percent	11,728,000	32.96
KN	5 to 10 percent with some 10 to 15 percent	1,261,440	3.55
KR KNR	5 to 10 percent with some 10 to 15 percent and some over 15 percent	663,680	1.87
NK	10 to 15 percent with some 5 to 10 percent	424,320	1.20
N	10 to 15 percent	3,607,040	10.14
NR NKR	10 to 15 percent with some 5 to 10 percent and some over 15 percent	476,160	1.34
	Total	35,575,040	100.00

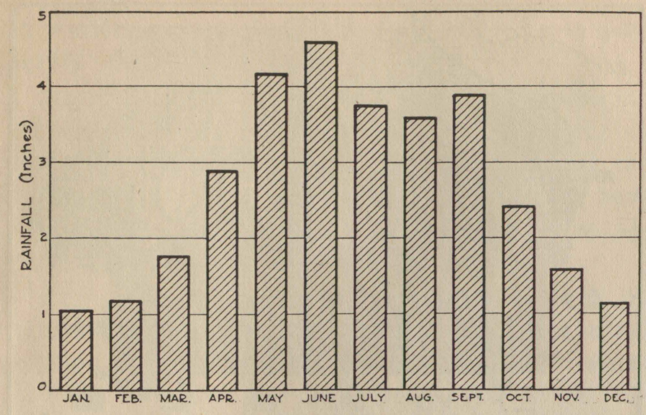

Fig. 4. Distribution of average normal monthly rainfall in Iowa.

the Tama silt loam of east-central Iowa are examples of soils whose structure has probably had some influence on their degree of erosion. In many respects these two soils appear to be similar, for they exhibit much the same topographic features and are similar in color. The Marshall silt loam, in general, however, has been eroded to a much greater extent than the Tama silt loam. Although the more intensive cropping to corn on the Marshall silt loam has been one of the major factors in bringing about this difference in erosion, the difference in erodibility presumably has also had some influence.

The organic matter content of soils is directly related to soil erodibility. Soils containing comparatively large amounts of organic matter have a mellow and friable structure which allows rapid penetration of rain water. Furthermore, organic matter acts much like a sponge in absorbing the rain water, thus increasing the absorptive capacity of the soil. These characteristics decrease the runoff water and hence the amount of soil erosion. Undoubtedly the high organic matter content of most Iowa soils limited the erosion which occurred during the early periods of their cultivation. As the organic matter content of soils is depleted through the continuous growing of inter-tilled crops and by improper soil management practices, however, the resistance of the soil to erosion is lessened.

These factors are all more or less intimately related, and it is the summation of their varied and combined effects on the soil that determines its erodibility, which, in turn, is of considerable importance in determining the extent to which it will erode under specific conditions of rainfall and soil and crop management. The characteristics of the individual soils will be discussed later in the section of this report dealing with the extent and seriousness of erosion in the various parts of Iowa.

Influence of Soil Management and Vegetative Cover on Erosion

One of the most important factors influencing soil erosion is the type of soil management and the cropping systems practiced. The importance of a vegetative cover of a thick-growing crop to prevent erosion cannot be over-emphasized. On the other hand, the frequent or continuous growing of inter-tilled crops on rolling to steep land greatly increases erosion, and it is this practice that has been most responsible for the loss of much of Iowa's fertile surface soil.

A striking example of the effects of the vegetative cover in controlling or preventing erosion is shown by the Clinton, Lindley and Shelby soils of southern Iowa. In areas where the original forest cover on these soils has been left intact there has been only a limited amount of erosion, and gullies have not developed. But in areas where the timber has been removed and the land has been subjected to intensive cropping on slopes of 5 percent or more, there has been severe erosion and gullies have formed at a tremendous rate. Another example is shown by the Fayette silt loam in northeastern Iowa. This soil has practically the same topography as the Clinton silt loam, and it is probably almost as erodible, but owing to the type of management generally followed and to the attention given to erosion control by the farmers of that area, it has been fairly well protected from the serious erosion that might have occurred. Much of the Clinton silt loam, on the other hand, has been rather badly eroded. Of far greater significance, however, is the fact that some farms on any soil type are much more badly eroded than neighboring ones where

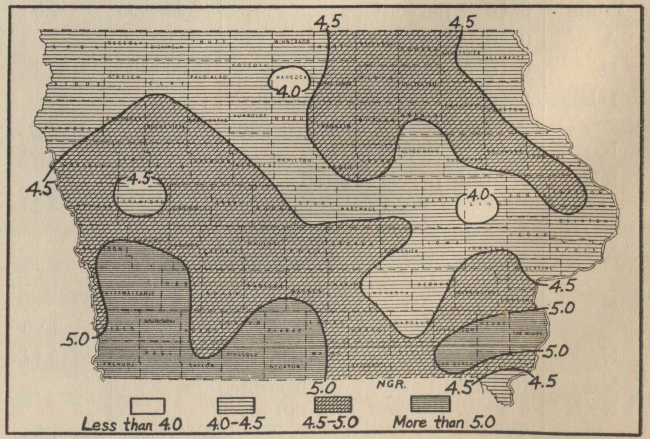

Fig. 5. June normal precipitation; average 4.58 inches. June is usually Iowa's wettest month.

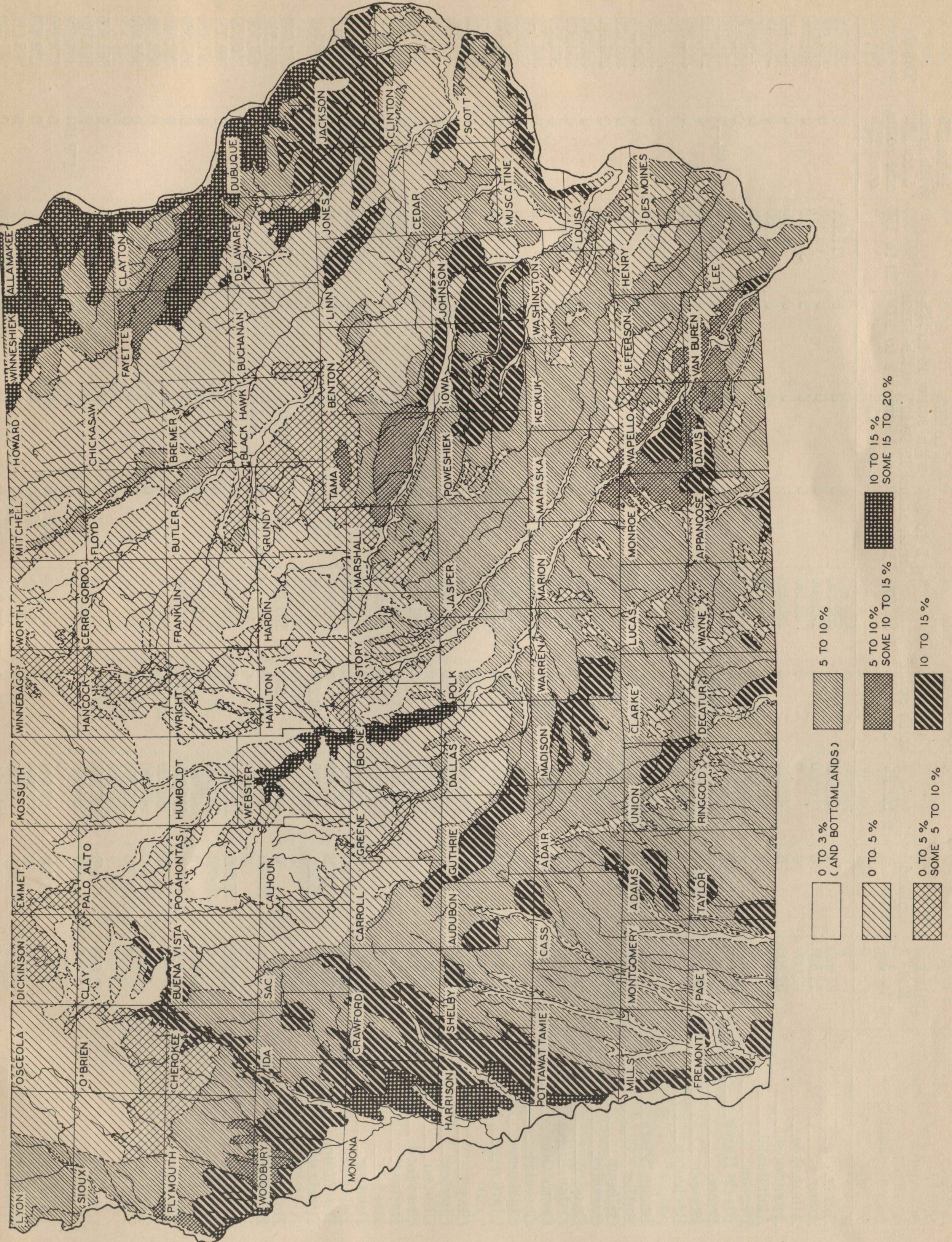

Fig. 6. Location and extent of land in various slope classes in Iowa.

TABLE 2. TOTAL ACREAGE BY COUNTIES OF THE DIFFERENT SLOPE CLASSES

County	Bottom-lands 0 to 3%	Uplands 0 to 3%	0 to 5%	0 to 5% with some 5 to 10%	5 to 10%	5 to 10% with some 10 to 15%	5 to 10% with some 10 to 15% and some over 15%	10 to 15% with some 5 to 10%	10 to 15%	10 to 15% with some 5 to 10% and some over 15%	Total acreage
Adair	0	0	39,040	0	309,760	0	0	0	17,920	0	366,720
Adams	11,520	0	0	0	192,000	0	0	0	69,760	0	273,280
Allamakee	32,000	0	0	0	45,440	0	0	0	331,520	0	408,960
Appanoose	38,400	0	42,240	0	196,480	0	0	0	51,200	0	328,320
Audubon	8,960	0	0	0	211,200	0	0	0	63,360	0	283,520
Benton	2,560	0	210,560	128,000	92,160	5,120	0	0	17,280	0	455,680
Black Hawk	80,640	0	129,280	151,680	0	0	0	0	0	0	361,600
Boone	0	37,760	211,200	30,720	15,360	0	0	0	0	69,120	364,160
Bremer	36,480	0	182,400	0	58,880	0	0	0	0	0	277,760
Buchanan	0	0	349,440	13,440	0	0	0	0	0	0	362,880
Buena Vista	0	0	294,400	0	42,240	0	0	28,800	0	0	365,440
Butler	61,440	0	216,960	47,360	43,520	0	0	0	0	0	369,280
Calhoun	0	248,320	111,360	3,840	0	0	0	0	0	0	363,520
Carroll	7,680	0	144,000	0	195,200	0	0	0	18,560	0	365,440
Cass	16,000	0	0	0	325,760	0	0	0	19,200	0	360,960
Cedar	5,760	0	160,640	0	170,240	0	0	0	28,160	0	364,800
Cerro Gordo	13,440	4,480	320,000	24,960	0	0	0	0	0	0	362,880
Cherokee	0	0	0	107,520	170,880	0	0	88,320	0	0	366,720
Chickasaw	0	0	296,320	0	21,760	0	0	0	0	0	318,080
Clarke	0	0	57,600	0	211,840	0	0	0	4,480	0	273,920
Clay	64,000	69,760	188,800	4,480	0	0	0	33,280	0	0	360,320
Clayton	3,200	0	16,000	0	151,680	64,000	250,240	2,560	0	0	487,680
Clinton	67,200	0	211,200	0	84,480	27,520	0	0	51,840	0	442,240
Crawford	16,000	0	0	0	201,600	0	0	0	240,000	0	457,600
Dallas	4,480	0	204,160	0	143,360	0	0	0	14,080	10,880	376,960
Davis	13,440	0	20,480	0	209,920	35,840	0	0	40,960	0	320,640
Decatur	21,760	0	43,520	0	231,040	0	0	0	44,800	0	341,120
Delaware	11,520	0	195,840	18,560	60,160	0	16,640	12,160	4,480	46,080	365,440
Des Moines	39,680	1,920	94,720	0	0	125,440	0	0	0	0	261,760
Dickinson	23,680	35,200	97,280	84,480	0	0	0	0	0	0	240,640
Dubuque	14,080	0	0	1,280	134,400	0	160,000	0	74,880	0	384,640
Emmet	3,200	55,680	59,520	133,120	0	0	0	0	0	0	251,520
Fayette	0	0	302,080	0	10,240	103,040	48,000	0	0	0	463,360
Floyd	26,240	76,800	177,920	0	35,840	0	0	0	0	0	316,800
Franklin	0	30,080	339,840	0	0	0	0	0	0	0	369,920
Fremont	135,040	0	0	0	120,320	0	0	0	69,120	0	324,480
Greene	7,040	0	280,320	58,240	31,760	0	0	0	0	0	367,360
Grundy	0	0	184,320	136,320	0	0	0	0	0	0	320,640
Guthrie	5,760	0	49,280	0	192,640	0	0	0	133,120	0	380,800
Hamilton	0	169,600	181,760	13,440	0	0	0	0	0	0	364,800
Hancock	41,600	45,440	157,440	120,320	0	0	0	0	0	0	364,800
Hardin	0	76,160	227,840	0	60,160	0	0	0	0	0	364,160
Harrison	152,320	0	0	0	0	0	0	0	157,440	132,480	442,240
Henry	14,080	23,680	96,640	0	0	138,880	0	0	0	0	273,280
Howard	0	0	271,360	0	12,160	16,000	0	0	0	0	299,520
Humboldt	36,480	179,200	60,160	0	0	0	0	0	0	0	275,840
Ida	0	0	0	0	209,280	0	0	0	65,920	0	275,200
Iowa	60,800	0	5,120	0	81,920	7,680	0	0	217,600	0	373,120
Jackson	25,600	0	2,560	0	29,440	43,520	0	0	303,360	0	404,480
Jasper	44,800	0	0	0	422,400	0	0	0	0	0	467,200
Jefferson	4,480	0	95,360	0	162,560	13,440	0	0	0	0	275,840
Johnson	56,320	0	72,320	0	67,840	0	0	0	193,920	0	390,400
Jones	6,400	0	180,480	14,080	0	0	0	0	163,200	0	364,160
Keokuk	27,520	0	48,000	0	294,400	0	0	0	0	0	369,920
Kossuth	8,960	124,800	488,960	0	0	0	0	0	0	0	622,720
Lee	51,840	0	80,000	0	182,400	0	0	0	12,800	0	327,040
Linn	1,920	0	297,600	0	28,800	0	0	0	125,440	0	453,760
Louisa	112,640	0	71,680	0	60,160	0	0	0	8,960	0	253,440
Lucas	0	0	15,360	16,000	234,880	0	0	0	10,240	0	276,480
Lyon	9,600	0	135,040	0	193,920	33,920	0	0	0	0	372,480
Madison	0	0	0	0	261,760	0	0	98,560	0	0	360,320
Mahaska	28,800	0	29,440	0	280,320	24,960	0	0	0	0	363,520
Marion	35,840	0	12,160	14,720	297,600	0	0	0	0	0	360,320
Marshall	28,160	1,280	72,960	98,560	137,600	27,520	0	0	0	0	366,080
Mills	77,440	0	0	0	152,960	0	0	0	49,920	0	280,320
Mitchell	2,560	48,000	209,280	0	36,480	0	0	0	0	0	296,320
Monona	228,480	0	0	0	8,320	0	0	0	77,440	124,800	439,040
Monroe	0	0	52,480	0	144,000	73,600	0	0	6,400	0	276,480
Montgomery	53,120	0	0	0	218,240	0	0	0	0	0	271,360
Muscatine	96,000	0	67,200	0	77,440	0	0	0	35,840	0	276,480
O'Brien	5,120	7,680	180,480	151,040	0	0	0	19,840	0	0	364,160
Osceola	1,280	12,160	233,600	5,760	0	0	0	0	0	0	252,800
Page	47,360	0	0	0	272,640	0	0	19,840	0	0	339,840
Palo Alto	35,200	129,920	183,680	10,240	0	0	0	0	0	0	359,040
Plymouth	19,200	0	0	35,840	305,920	58,240	0	0	128,640	0	537,840
Pocahontas	5,760	245,120	117,760	0	0	0	0	0	0	0	368,640
Polk	76,160	96,000	24,320	0	174,720	0	0	0	0	1,280	372,480
Pottawattamie	92,160	0	0	0	355,200	0	0	0	155,520	0	602,880
Poweshiek	0	0	26,880	0	272,640	1,920	0	0	69,760	0	371,200
Ringgold	0	0	43,520	0	300,800	0	0	0	1,280	0	345,600
Sac	0	0	190,080	0	160,000	0	0	0	17,280	0	367,360
Scott	36,480	0	115,200	0	72,960	0	0	0	62,720	0	287,360
Shelby	22,400	0	0	0	280,960	0	0	0	73,600	0	376,960
Sioux	26,880	0	150,400	113,280	183,040	12,800	0	0	0	0	486,400
Story	28,800	113,280	97,280	6,400	117,120	0	0	0	0	0	362,880
Tama	26,880	0	0	128,000	133,760	172,160	0	0	0	0	460,800
Taylor	3,840	0	0	0	286,720	0	0	51,200	0	0	341,760
Union	0	0	42,880	0	184,960	0	0	0	45,440	0	273,280
Van Buren	36,480	0	55,680	0	97,920	113,920	0	0	1,280	0	305,280
Wapello	28,800	0	51,840	0	43,520	91,520	0	0	58,240	0	273,920
Warren	17,920	0	17,280	0	272,000	0	0	57,600	0	0	364,800
Washington	32,000	0	118,400	0	202,880	0	0	0	4,480	0	357,760
Wayne	0	0	106,240	0	220,800	0	0	0	8,320	0	335,360
Webster	0	74,240	300,160	0	0	0	0	0	0	82,560	456,960
Winnebago	8,960	0	152,320	94,080	0	0	0	0	0	0	255,360
Winneshiek	0	0	96,000	0	154,240	0	188,800	0	0	0	439,040
Woodbury	124,160	0	0	0	80,000	70,400	0	12,160	257,280	8,960	552,960
Worth	1,920	76,800	147,840	28,800	0	0	0	0	0	0	255,360
Wright	14,080	127,360	195,840	30,720	0	0	0	0	0	0	368,000
Total	2,668,800	2,110,720	10,809,600	1,825,280	11,728,000	1,261,440	663,680	424,320	3,607,040	476,160	35,575,040

proper soil management practices have prevented erosion.

The system of soil management and vegetative cover is the factor influencing erosion that can be controlled by the farmer. Nothing can be done to modify the rainfall nor the general topography of the land; little can be done to modify the erodibility of the soil and that only through the soil management practices adopted. A more complete consideration of the influence of this factor will be given in another section of this bulletin, which deals with the methods used for the successful control of erosion.

EXTENT AND SERIOUSNESS OF SOIL EROSION IN IOWA

The results obtained in the reconnaissance erosion survey of Iowa have been summarized and are presented in table 3. These data reveal the important facts: (1) That only about 13 percent of the total land of the state shows little or no erosion; (2) that approximately a third of the land shows slight sheet erosion and that up to 25 percent of the original surface soil has been washed away; (3) that over 14 percent of the land has lost from 25 to 50 percent of its surface soil by erosion, and that most of this area shows occasional to moderate gullying; (4) that about 31 percent of the land has been seriously eroded, and 50 to 75 percent of the original fertile surface soil washed away; that this land has also been moderately to excessively gullied; and (5) that about 9 percent of the land of Iowa has been severely eroded, having lost 75 percent or more of the original surface soil; that there has also been moderate to excessive gullying in this area.

The results of this survey are presented in greater detail in table 4 (page 16) where the total acreage of the different classes of erosion is given for each county. The map in fig. 7 shows in detail the location and extent of the various classes of soil erosion within the state.

In order to show the erosion picture more broadly and in less detail, certain classes of erosion have been combined, and these are shown on the colored map in the pocket attached to the inside back cover of this bulletin. In preparing this general map the areas of upland soil showing little or no sheet erosion and slight sheet erosion have been grouped together and are shown in gray. Practically all of the large area of drift soils in north central Iowa, and the comparatively flat Muscatine soils of southeastern Iowa are included in this class.

In interpreting the colored map one should not draw the conclusion that the soils of these areas are not subject to erosion, nor that there is no erosion occurring in them. The data of table 4 and the map in fig. 7 show that although these are the areas in which there has been the least erosion in the state, they contain considerable acreages of land that have been affected materially by sheet erosion, although gully erosion has not developed extensively. Sheet erosion on the steeper slopes is very noticeable on bare land after a period of intensive rainfall. A more detailed discussion of erosion in these areas is given later.

In a similar manner the areas indicated in table 4 as showing moderate and serious sheet erosion were grouped into a single class on the colored map. The areas showing severe sheet erosion on the map are practically the same as those indicated by the data of table 4.

On the basis of the data of table 4 and a knowledge of the depth of the original surface soils, estimates have been made of the depth of the surface

TABLE 3. TOTAL AND PERCENTAGE ACREAGE IN 10 EROSION CLASSES OF IOWA SOIL

Erosion class	Description	Total acreage in Iowa	Percentage of total land area
Bottom-land	River bottom land not eroded but subject to overflow from adjoining uplands	2,668,800	7.50
00	Level to flat upland with little or no erosion	2,125,440	5.97
10	Slight sheet erosion with practically no gully formation	11,336,320	31.87
17	Slight sheet erosion with occasional to moderate gullying	456,320	1.28
20	Moderate sheet erosion with practically no gullying	1,115,520	3.14
27	Moderate sheet erosion with occasional to moderate gullying	3,602,560	10.13
37	Serious sheet erosion with occasional to moderate gullying	8,819,200	24.79
38	Serious sheet erosion with serious to excessive gullying	2,245,120	6.31
47	Severe sheet erosion with occasional to moderate gullying	218,240	0.61
48	Severe sheet erosion with serious to excessive gullying	2,987,520	8.40
	Total	35,575,040	100.00

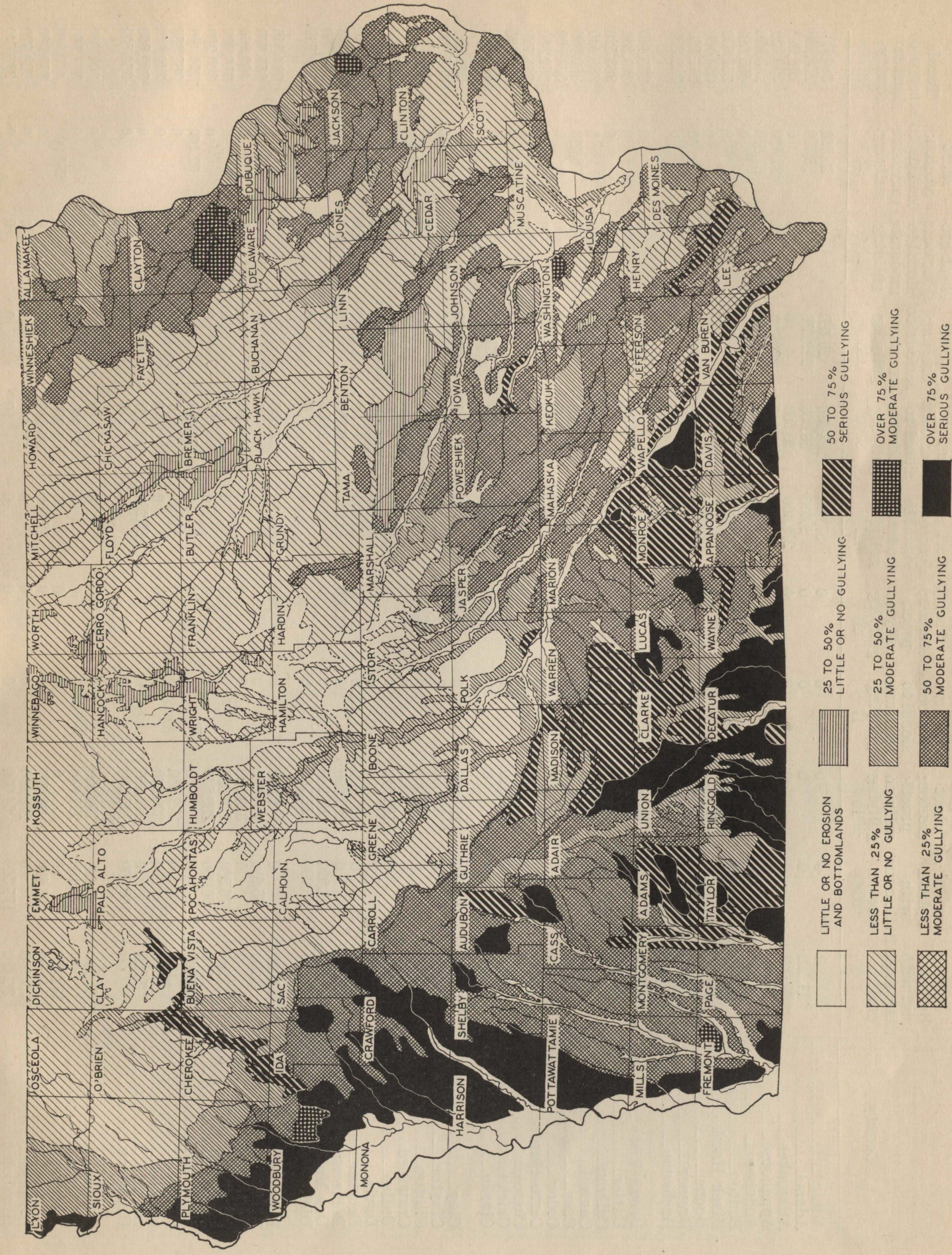

Fig. 7. Location and extent of land in the various classes of soil erosion in Iowa.

TABLE 4. TOTAL ACREAGE BY COUNTIES OF THE DIFFERENT CLASSES OF SOIL EROSION

County	Bottom-land with little or no erosion	Upland with little or no erosion 00	Slight sheet erosion; practically no gullying 10	Slight sheet erosion; occasional to moderate gullying 17	Moderate sheet erosion; practically no gullying 20	Moderate sheet erosion; occasional to moderate gullying 27	Serious sheet erosion; occasional to moderate gullying 37	Serious sheet erosion; serious to excessive gullying 38	Severe sheet erosion; occasional to moderate gullying 47	Severe sheet erosion; serious to excessive gullying 48	Total acreage of land in county
Adair	0	0	0	0	0	87,040	208,640	20,480	0	50,560	366,720
Adams	11,520	0	0	0	0	9,600	56,960	119,680	0	75,520	273,280
Allamakee	32,000	0	0	0	0	278,400	98,560	0	0	0	408,960
Appanoose	38,400	0	0	12,800	0	56,960	135,040	53,120	0	32,000	328,320
Audubon	8,960	0	0	0	0	5,760	150,400	50,560	0	67,840	283,520
Benton	2,560	0	182,400	0	177,920	45,440	47,360	0	0	0	455,680
Black Hawk	80,640	0	280,960	0	0	0	0	0	0	0	361,600
Boone	0	1,920	277,760	0	0	84,480	0	0	0	0	364,160
Bremer	36,480	0	183,040	0	58,240	0	0	0	0	0	277,760
Buchanan	0	0	324,480	0	0	38,400	0	0	0	0	362,880
Buena Vista	0	0	336,640	0	0	0	0	28,800	0	0	365,440
Butler	61,440	0	261,760	0	46,080	0	0	0	0	0	369,280
Calhoun	0	248,320	115,200	0	0	0	0	0	0	0	363,520
Carroll	7,680	0	143,360	0	0	3,840	210,560	0	0	0	365,440
Cass	16,000	0	0	0	0	10,880	297,600	17,920	0	18,560	360,960
Cedar	5,760	0	118,400	0	39,680	54,400	146,560	0	0	0	364,800
Cerro Gordo	13,440	4,480	320,000	0	24,960	0	0	0	0	0	362,880
Cherokee	0	0	104,960	97,280	0	76,160	0	88,320	0	0	366,720
Chickasaw	0	0	296,320	0	21,760	0	0	0	0	0	318,080
Clarke	0	0	0	0	0	53,120	14,720	183,680	0	0	273,920
Clay	64,000	69,760	184,960	0	1,920	0	0	39,680	0	0	360,320
Clayton	3,200	0	18,560	0	0	34,560	312,960	0	118,400	0	487,680
Clinton	67,200	0	199,680	0	32,640	0	142,720	0	0	0	442,240
Crawford	16,000	0	0	0	0	0	201,600	0	0	240,000	457,600
Dallas	4,480	0	195,840	0	0	147,200	0	29,440	0	0	376,960
Davis	13,440	0	0	0	0	69,120	32,640	132,480	0	72,960	320,640
Decatur	21,760	0	0	5,120	0	38,400	0	51,840	0	224,000	341,120
Delaware	11,520	0	192,000	0	72,320	12,800	76,800	0	0	0	365,440
Des Moines	39,680	1,920	97,280	0	0	0	112,000	10,880	0	0	261,760
Dickinson	23,680	35,200	181,760	0	0	0	0	0	0	0	240,640
Dubuque	14,080	0	9,600	0	120,960	144,000	96,000	0	0	0	384,640
Emmet	3,200	55,680	154,240	0	38,400	0	0	0	0	0	251,520
Fayette	0	0	313,600	0	0	0	149,760	0	0	0	463,360
Floyd	26,240	76,800	177,920	0	35,840	0	0	0	0	0	316,800
Franklin	0	30,080	339,840	0	0	0	0	0	0	0	369,920
Fremont	135,040	0	0	0	0	0	73,600	0	23,680	92,160	324,480
Greene	7,040	0	279,680	0	0	80,640	0	0	0	0	367,360
Grundy	0	0	320,640	0	0	0	0	0	0	0	320,640
Guthrie	5,760	0	49,280	0	0	113,280	182,400	30,080	0	0	380,800
Hamilton	0	169,600	195,200	0	0	0	0	0	0	0	364,800
Hancock	41,600	45,440	156,800	0	120,960	0	0	0	0	0	364,800
Hardin	0	76,160	227,840	0	0	0	60,160	0	0	0	364,160
Harrison	152,320	0	0	0	0	0	1,920	0	0	288,000	442,240
Henry	14,080	23,680	98,560	0	0	12,800	90,240	33,920	0	0	273,280
Howard	0	0	270,080	0	0	0	29,440	0	0	0	299,520
Humboldt	36,480	175,360	64,000	0	0	0	0	0	0	0	275,840
Ida	0	0	0	28,800	0	0	179,840	13,440	0	53,120	275,200
Iowa	60,800	0	16,000	0	64,640	8,960	192,000	30,720	0	0	373,120
Jackson	25,600	0	3,200	0	4,480	44,160	306,560	0	20,480	0	404,480
Jasper	44,800	0	16,000	0	0	157,440	248,960	0	0	0	467,200
Jefferson	4,480	0	8,960	85,760	0	0	163,200	13,440	0	0	275,840
Johnson	56,320	0	117,760	0	0	22,400	193,920	0	0	0	390,400
Jones	6,400	0	137,600	0	15,360	37,120	167,680	0	0	0	364,160
Keokuk	27,520	0	30,720	1,920	0	106,880	202,880	0	0	0	369,920
Kossuth	8,960	124,800	488,960	0	0	0	0	0	0	0	622,720
Lee	51,840	24,960	0	55,040	0	0	165,760	29,440	0	0	327,040
Linn	1,920	0	258,560	0	32,640	19,840	140,800	0	0	0	453,760
Louisa	112,640	0	70,400	0	0	6,400	64,000	0	0	0	253,440
Lucas	0	0	0	5,760	0	33,920	154,240	9,600	0	72,960	276,480
Lyon	9,600	0	131,200	3,840	0	193,920	0	0	0	33,920	372,480
Madison	0	0	0	0	0	78,080	9,600	255,360	0	17,280	360,320
Mahaska	28,800	0	32,640	0	0	82,560	172,160	37,760	0	9,600	363,520
Marion	35,840	0	12,160	4,480	0	24,320	256,000	27,520	0	0	360,320
Marshall	28,160	1,280	153,600	0	9,600	138,880	34,560	0	0	0	366,080
Mills	77,440	0	0	0	0	5,120	145,280	0	0	52,480	280,320
Mitchell	2,560	48,000	245,760	0	0	0	0	0		0	296,320
Monona	228,480	0	0	0	0	0	8,320	0	0	202,240	439,040
Monroe	0	0	5,120	51,840	0	5,120	0	214,400	0	0	276,480
Montgomery	53,120	0	0	0	0	12,160	163,840	42,240	0	0	271,360
Muscatine	96,000	0	90,240	0	0	62,720	27,520	0	0	0	276,480
O'Brien	5,120	7,680	301,440	0	0	28,800	0	21,120	0	0	364,160
Osceola	1,280	14,720	231,680	0	5,120	0	0	0	0	0	252,800
Page	47,360	0	0	0	0	5,120	230,400	31,360	0	25,600	339,840
Palo Alto	35,200	129,920	183,680	0	10,240	0	0	0	0	0	359,040
Plymouth	19,200	0	35,840	0	0	144,000	156,800	0	0	192,000	547,840
Pocahontas	5,760	245,120	117,760	0	0	0	0	0	0	0	368,640
Polk	76,160	96,000	24,320	0	0	163,840	3,840	8,320	0	0	372,480
Pottawattamie	92,160	0	0	0	0	0	351,360	0	0	159,360	602,880
Poweshiek	0	0	16,000	5,120	0	17,280	332,800	0	0	0	371,200
Ringgold	0	0	0	0	0	69,760	0	21,760	0	254,080	345,600
Sac	0	0	192,000	39,680	0	0	115,840	0	0	19,840	367,360
Scott	36,480	0	111,360	0	0	28,160	111,360	0	0	0	287,360
Shelby	22,400	0	0	0	0	12,160	273,280	0	0	69,120	376,960
Sioux	26,880	0	248,320	0	0	154,880	43,520	0	0	12,800	486,400
Story	28,800	140,160	142,080	0	0	51,840	0	0	0	0	362,880
Tama	26,880	0	123,520	0	83,840	35,840	190,720	0	0	0	460,800
Taylor	3,840	0	0	7,040	0	67,840	0	197,120	0	65,920	341,760
Union	0	0	0	0	0	39,680	71,040	31,360	0	131,200	273,280
Van Buren	36,480	0	0	51,840	0	23,040	71,880	122,240	0	0	305,280
Wapello	28,800	0	54,400	0	0	0	48,000	83,200	0	59,520	273,920
Warren	17,920	0	18,560	0	0	19,200	188,800	119,040	0	1,280	364,800
Washington	32,000	0	113,280	0	0	5,760	194,560	0	12,160	0	357,760
Wayne	0	0	0	0	0	102,400	97,280	28,160	0	107,520	335,360
Webster	0	74,240	300,160	0	0	82,560	0	0	0	0	456,960
Winnebago	8,960	0	196,480	0	49,920	0	0	0	0	0	255,360
Winneshiek	0	0	78,720	0	0	38,400	321,920	0	0	0	439,040
Woodbury	124,160	0	0	0	0	14,720	90,240	16,640	43,520	263,680	552,960
Worth	1,920	76,800	159,360	0	17,280	0	0	0	0	0	255,360
Wright	14,080	127,360	195,840	0	30,720	0	0	0	0	0	368,000
Total	2,668,800	2,125,440	11,336,320	456,320	1,115,520	3,602,560	8,819,200	2,245,120	218,240	2,987,520	35,575,040

soil present in the various parts of the state. A summary of these data giving the acreage of land with different depths of surface soils is shown in table 5, and the detailed data by counties are given in table 6 (page 20). The location and extent of the soils of different depths are shown on the map in fig. 8.

The data presented in the various tables, and illustrated in the maps, show definitely that there has been an enormous loss of the fertile surface soil over large areas. The loss of soil has been so great that much of the land has only a very thin cover of fertile top soil remaining, and on many acres only the less fertile subsoil remains. On small areas on many farms the land has been so completely dissected by gullies that it can no longer be cultivated, and an enormous amount of land has been gullied to the extent that it is now difficult to cultivate with the common farm machinery. Furthermore, erosion is in the incipient stage on much of the land in the state where the evidences are not so readily recognized at present. Unless serious consideration is given to the prevention of erosion on these lands, it will undoubtedly rapidly increase, and in time this land will be affected to the same extent as those lands that are now nearly ruined.

In summarizing the data as a whole, it has been estimated that approximately 30 billion tons of soil have been washed away from Iowa land since its cultivation was begun. This is equivalent to a loss of approximately 35 percent of the original surface soil on the average Iowa farm. It is obvious, however, that a much greater percentage of the surface soil than this has been lost in areas where erosion has been most severe.

With this loss of surface soil there has been a tremendous loss of plant nutrients. It is estimated

TABLE 5. THE TOTAL AND PERCENTAGE ACREAGES OF SOILS OF DIFFERENT DEPTHS IN IOWA

Depth of surface soil	Total acreage in Iowa	Percentage of total land area
Bottomland of variable depth	2,668,800	7.50
Soils with surface 12 inches deep or deeper	3,061,120	8.60
Soils with surface 8 to 12 inches deep	12,212,480	34.33
Soils with surface 4 to 8 inches deep	14,566,400	40.95
Soils with surface 4 inches or less in depth	3,066,240	8.62
Total	35,575,040	100.00

that about 55 million tons of nitrogen, 18 million tons of phosphorus and 455 million tons of potassium have been carried away from the farms of Iowa by erosion. This is equivalent to a loss of about 247 tons of nitrogen, 82 tons of phosphorus and 2,046 tons of potassium for the average size Iowa farm of 160 acres. On the basis of the present price of commercial fertilizers containing these plant nutrients this loss would amount to a little less than $3,000 per acre of land. Although this appears to be more than the land is worth, it emphasizes the fact that the capital value of Iowa farms is being depleted by erosion, and that this depletion is actually far greater than the market value of the land. This vast loss in capital stock to Iowa agriculture emphasizes further the need for immediate and concerted action to control soil erosion

EROSION IN THE VARIOUS SOIL AREAS

Inasmuch as the erodibility of soils and the seriousness of erosion are closely associated with the soil type, and as each upland soil type occurs mainly in a certain soil area, it has been deemed advisable to discuss the erosion problem in Iowa on the basis of the five large soil areas of the state and soil types occurring in them. The discussion will be divided into five major sections, therefore, each dealing with a particular soil area.

There are five large soil areas in the state, the divisions being based upon the origin and characteristics of the soils. These are the Missouri loess, the Southern Iowa loess, the Mississippi loess, the Iowan drift and the Wisconsin drift areas, and are shown on the map in fig. 9 (page 22). Principal soil types of the state are shown in fig. 10 (page 23).

The Missouri Loess Soil Area

This area lies in the western portion of the state, and consists of a strip of loessial soil from the northern to the southern boundary, about two and one-half to three counties wide, extending from the Missouri River east 50 to 75 miles. The loess material is extremely variable in depth. In the western part of the area it is 100 feet or more deep, but progressing to the east it gradually becomes shallower until on the eastern border of the area it is only a few feet deep in many places. The area is also rather variable in topography. Regarded as a unit, it has the topographic features of a dissected plain with a gentle slope from north to south, and from east to west. Most of the streams have a southerly and southwesterly direction.

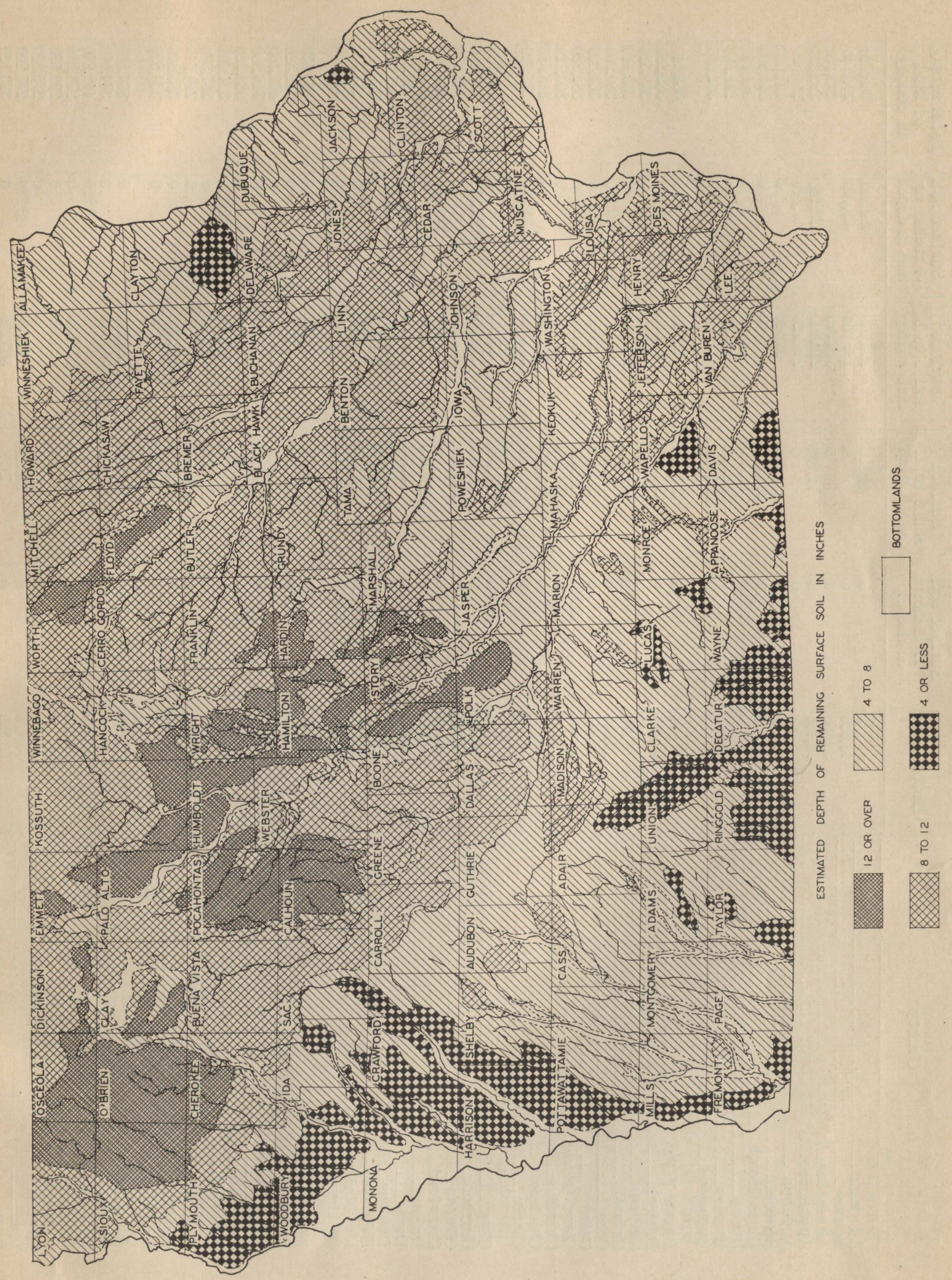

Fig. 8. Location and extent of the soils of different depths in Iowa.

TABLE 6. TOTAL ACREAGE BY COUNTIES OF SOIL OF DIFFERENT DEPTHS

County	Bottomland	Surface soil 12 inches or deeper	Surface soil 8 to 12 inches deep	Surface soil 4 to 8 inches deep	Surface soil 4 inches or less in depth	Total acreage of land in county
Adair	0	0	40,320	265,600	60,800	366,720
Adams	11,520	0	0	192,000	69,760	273,280
Allamakee	32,000	0	0	376,960	0	408,960
Appanoose	38,400	0	12,160	249,600	28,160	328,320
Audubon	8,960	0	0	206,720	67,840	283,520
Benton	2,560	0	404,480	48,640	0	455,680
Black Hawk	80,640	0	280,960	0	0	361,600
Boone	0	53,760	232,320	78,080	0	364,160
Bremer	36,480	0	183,040	58,240	0	277,760
Buchanan	0	0	324,480	38,400	0	362,880
Buena Vista	0	0	333,440	32,000	0	365,440
Butler	61,440	0	275,200	32,640	0	369,280
Calhoun	0	248,320	111,360	3,840	0	363,520
Carroll	7,680	0	139,520	218,240	0	365,440
Cass	16,000	0	5,760	320,000	19,200	360,960
Cedar	5,760	0	166,400	192,640	0	364,800
Cerro Gordo	13,440	3,840	320,640	24,960	0	362,880
Cherokee	0	111,360	174,080	81,280	0	366,720
Chickasaw	0	0	296,320	21,760	0	318,080
Clarke	0	0	0	255,360	18,560	273,920
Clay	64,000	70,400	178,560	47,360	0	360,320
Clayton	3,200	0	18,560	354,560	111,360	487,680
Clinton	67,200	0	252,800	122,240	0	442,240
Crawford	16,000	0	0	217,600	224,000	457,600
Dallas	4,480	0	229,760	142,720	0	376,960
Davis	13,440	0	5,760	234,880	66,560	320,640
Decatur	21,760	0	3,200	113,280	202,880	341,120
Delaware	11,520	0	206,080	147,840	0	365,440
Des Moines	39,680	1,920	94,720	125,440	0	261,760
Dickinson	23,680	32,000	184,960	0	0	240,640
Dubuque	14,080	0	9,600	360,960	0	485,650
Emmet	3,200	55,040	157,440	35,840	0	251,520
Fayette	0	0	313,600	149,760	0	463,360
Floyd	26,240	76,800	177,920	35,840	0	316,800
Franklin	0	32,640	337,280	0	0	369,920
Fremont	135,040	0	0	72,960	116,480	324,480
Greene	7,040	0	277,120	83,200	0	367,360
Grundy	0	0	320,640	0	0	320,640
Guthrie	5,760	0	82,560	292,480	0	380,800
Hamilton	0	169,600	195,200	0	0	364,800
Hancock	41,600	45,440	154,240	123,520	0	364,800
Hardin	0	76,160	227,840	60,160	0	364,160
Harrison	152,320	0	0	0	289,920	442,240
Henry	14,080	23,680	96,640	138,880	0	273,280
Howard	0	0	270,080	29,440	0	299,520
Humboldt	36,480	186,240	53,120	0	0	275,840
Ida	0	0	33,920	192,000	49,280	275,200
Iowa	60,800	0	7,040	305,280	0	373,120
Jackson	25,600	0	4,480	353,920	20,480	404,480
Jasper	44,800	0	19,840	402,560	0	467,200
Jefferson	4,480	0	96,000	175,360	0	275,840
Johnson	56,320	0	119,680	214,400	0	390,400
Jones	6,400	0	183,040	174,720	0	364,160
Keokuk	27,520	0	51,200	291,200	0	369,920
Kossuth	8,960	124,800	488,960	0	0	622,720
Lee	51,840	0	80,000	195,200	0	327,040
Linn	1,920	0	286,720	165,120	0	453,760
Louisa	112,640	0	74,240	66,560	0	253,440
Lucas	0	0	0	215,040	61,440	276,480
Lyon	9,600	131,200	197,760	0	33,920	372,480
Madison	0	0	88,960	254,720	16,640	360,320
Mahaska	28,800	0	31,360	303,360	0	363,520
Marion	35,840	0	14,080	310,400	0	360,320
Marshall	28,160	1,280	177,920	158,720	0	366,080
Mills	77,440	0	0	152,960	49,920	280,320
Mitchell	2,560	10,240	283,520	0	0	296,320
Monona	228,480	0	0	16,000	194,560	439,040
Monroe	0	0	52,480	224,000	0	276,480
Montgomery	53,120	0	0	218,240	0	271,360
Muscatine	96,000	0	81,280	99,200	0	276,480
O'Brien	5,120	307,200	0	51,840	0	364,160
Osceola	1,280	157,440	87,680	6,400	0	252,800
Page	47,360	0	0	272,640	19,840	339,840
Palo Alto	35,200	130,560	187,520	5,760	0	359,040
Plymouth	19,200	35,840	145,920	160,000	186,880	547,840
Pocahontas	5,760	245,120	117,760	0	0	368,640
Polk	76,160	94,720	44,160	157,440	0	372,480
Pottawattamie	92,160	0	0	353,280	157,440	602,880
Poweshiek	0	0	28,800	342,400	0	371,200
Ringgold	0	0	0	108,160	237,440	345,600
Sac	0	0	233,600	117,760	16,000	267,360
Scott	36,480	0	113,280	137,600	0	287,360
Shelby	22,400	0	0	280,960	73,600	376,960
Sioux	26,880	273,280	134,400	40,960	10,880	486,400
Story	28,800	119,680	156,800	57,600	0	362,880
Tama	26,880	0	213,760	220,160	0	460,800
Taylor	3,840	0	0	273,920	64,000	341,760
Union	0	0	0	147,200	126,080	273,280
Van Buren	36,480	0	51,200	217,600	0	305,280
Wapello	28,800	0	51,840	135,040	58,240	273,920
Warren	17,920	0	33,920	311,680	1,280	364,800
Washington	32,000	0	110,080	215,680	0	357,760
Wayne	0	0	0	231,040	104,320	335,360
Webster	0	43,520	327,680	85,760	0	456,960
Winnebago	8,960	0	192,640	53,760	0	255,360
Winneshiek	0	0	78,720	360,320	0	439,040
Woodbury	124,160	0	14,720	105,600	308,480	552,960
Worth	1,920	71,680	171,520	10,240	0	255,360
Wright	14,080	127,360	195,840	30,720	0	368,000
Total	2,668,800	3,061,120	12,212,480	14,566,400	3,066,240	35,575,040

Soils of the Missouri Loess Area

The principal soil type of this area is the *Marshall silt loam* which covers practically the entire upland. Some counties are made up of as much as 80 percent or more of this soil. It is the chief agricultural soil of the area, and it is also generally the most productive.

The soil in the virgin state is a very dark, grayish-brown friable silt loam, extending, in general, to a depth of 18 to 24 inches, and in many places the original surface soil was even deeper. Below this depth the subsoil is yellowish-brown or buff-colored. As a result of the washing away of the surface, however, the soil is often considerably less than 18 inches deep where it has been cultivated, and the depth of the surface soil in cultivated fields varies from the original depth to zero on the steeper slopes.

Other important soils of the area are those of the Knox and Shelby series and the terrace and bottomland soils. The *Knox* series occurs, in the main, in a rather narrow strip of variable width along the eastern edge of the Missouri River, constituting the bluffs region. This soil also occurs along the lower courses of the larger streams. It has a thin grayish-brown friable covering over the yellow parent loess. In many places the surface soil has been entirely removed by erosion and the yellow or brown silt loam subsoil is exposed. In the counties not adjacent to the Missouri River this soil covers only about 0.1 percent or less of the area, while in counties along the river the area of this soil is larger, covering, for example, 6.4 percent of the area in Fremont County.

The *Shelby loam* occurs in numerous small areas separating the Marshall silt loam on the uplands from the bottomland, principally in the southeastern

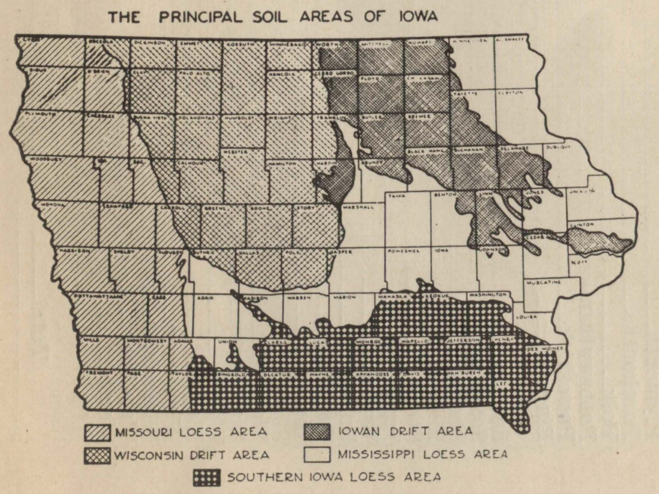

Fig. 9. Principal soil areas of Iowa.

portion of the soil area. It is of drift origin and occurs where the loess mantle has been washed away exposing the underlying drift material.

The terrace and bottomlands of the area cover an appreciable percentage of the counties adjoining the Missouri River. Due to their prevailingly level topography, however, these soils in general have been eroded very little. They will not, therefore, be discussed in detail. This applies also to the terrace and bottomlands of the other soil areas.

Topography and Degree of Slope

The mantle of loess in this area has been deposited largely upon Wisconsin and Kansan drift material. Undoubtedly the glacial drift had been eroded prior to deposition of the silt, and in some places erosion had probably progressed to a marked degree. The topography of the drift thus being variable, with some slopes much steeper than others, it is not surprising that there are now striking differences in the slopes of the land in different parts of the area.

In the upper portion of the region, particularly in the eastern part of Sioux and Lyon counties and in Osceola and O'Brien counties, the loess is found upon level or very gently rolling land. To the southward, however, the slopes become more pronounced. In the same manner, the individual valleys, having rather gentle slopes near their heads, have more steeply rolling topography in their lower reaches. Thus, the degree of erosion is much less in the northern portions of the region than in the southern parts. Likewise, in individual valleys in general, although there are numerous exceptions, the erosion is more marked in the lower portions.

Eastward from the Missouri River there is also a transition from steep to gentle slopes. Throughout the bluff region, where the Knox soils predominate, the slopes range from 15 to 40 percent or more. Many of these slopes should not be in cultivation, but, nevertheless, they are frequently planted to corn. Along the eastern margins of the area the slopes become more gentle, but owing to the thinner mantle of loess the erosion is frequently severe. The erosion within individual valleys commonly parallels that of the region as a whole. The valley sides facing eastward, with their deeper deposition of silt, frequently show less erosion than the valley sides facing westward.

In general, the slopes on the Marshall silt loam in the extreme northern portion of the area range from 0 to 3 percent. To the southward the slopes become steeper, ranging from 5 to 10 percent in

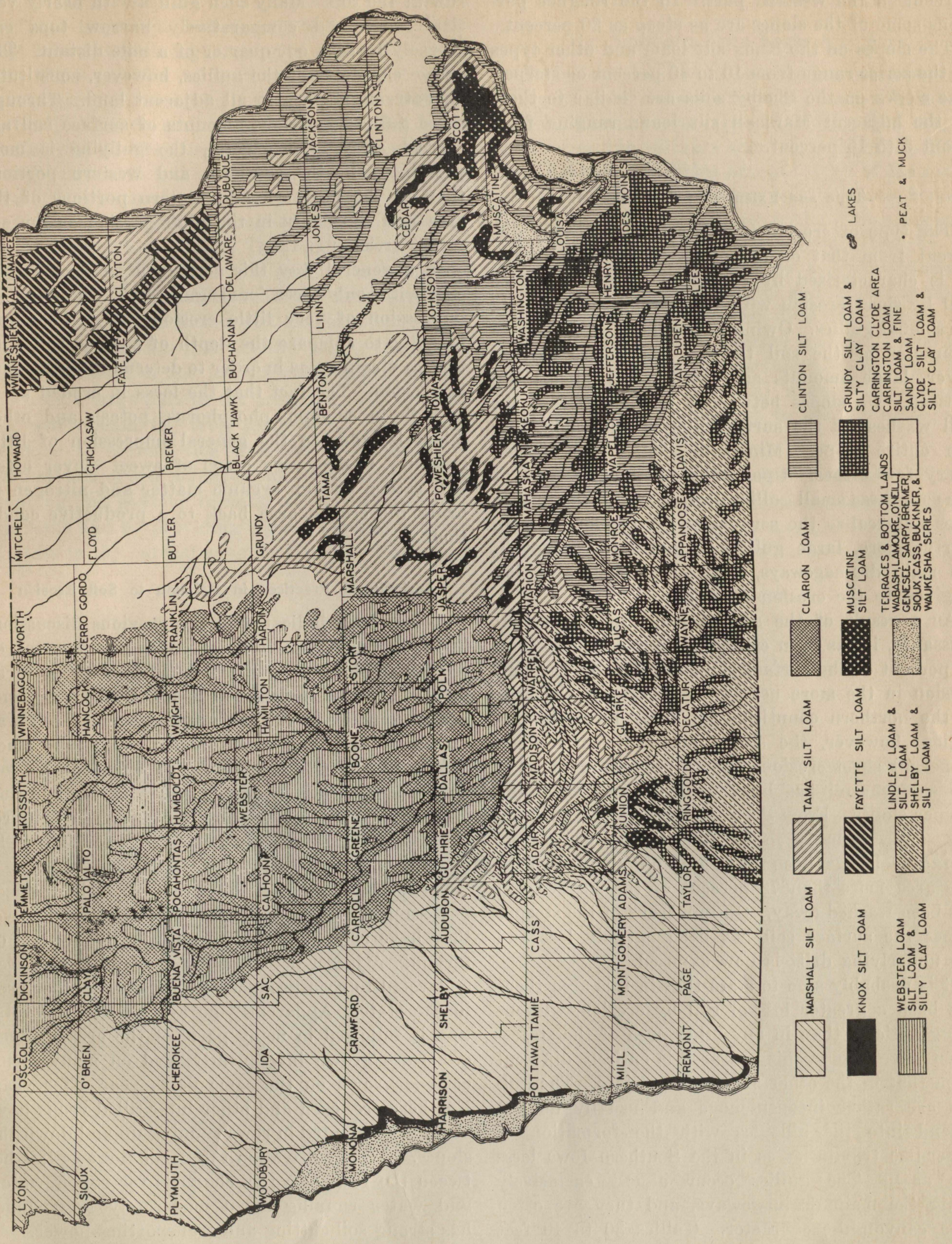

Fig. 10. Principal soil types of Iowa.

the eastern part of the area and from 10 to 15 percent in the western part. In the rougher portions some of the slopes are as steep as 20 percent.

The slopes on the Knox silt loam and other types of the series range from 10 to 40 percent or steeper. The slopes on the Shelby soils are similar to those of the adjacent Marshall silt loam, ranging from about 5 to 15 percent.

Type and Extent of Soil Erosion

The type of erosion in this soil area is very different from that of the other areas of the state. It is characterized by enormous losses of surface soil by sheet erosion with the development of only occasional gullies. Owing to the depth and uniform character of the soil through the entire surface layer, large amounts may wash away almost unnoticed. On slopes between 5 and 10 percent the soil washes off the surface almost uniformly over the entire slope. Miniature gullies are formed every few inches. Upon subsequent cultivation of the soil, these small gullies disappear and the farmer does not realize the seriousness of the loss of soil. Furthermore, large gullies do not form except in the main drainageways, and, hence, little attention is given to the erosion situation.

As a result of the studies made in this reconnaissance, it has been estimated that not more than 25 percent of the surface soil has been lost through erosion in the more nearly level parts of the area in the northern counties. On many farms in this region, however, the slopes are sufficiently steep to permit sheet erosion, and 25 percent or more of the surface soil has been washed away from the steeper slopes. From Plymouth and Cherokee counties south, from 25 to 50 percent or more of the surface soil has been lost, and on about half of this area more than 75 percent of the surface soil has been washed away. On numerous of the steeper slopes the surface soil has been entirely lost and the underlying drift is now exposed.

It is probably safe to state that in this area there has been a greater loss of soil by erosion, without being noticed, than in any other area of the state.

Gully erosion in this soil area is entirely different from that in the other areas of the state. The gullies are rather inconspicuous and usually do not extend into the hillsides with the formation of finger-like tributaries as in the Southern Iowa loess soil area. The gullies occur almost exclusively along the main drainageways, and they are often of a canyon-like character. Gullies 30 to 40 feet deep were found, and many of them were 15 to 25 feet deep, although they were comparatively narrow at the top. Many such gullies with nearly vertical sides and comparatively narrow tops can scarcely be seen one-quarter of a mile distant. The active character of the gullies, however, constitutes an extreme menace to all adjacent land. Through these gullies enormous amounts of surface soil are carried away. In general, the gullying is more prominent in the southern and western portions than in the northern and eastern portions of the area and especially in the bluff portion or the adjacent areas (fig. 12).

In a general way this area may be regarded as one with only occasional gullies. This gives an impression of very little erosion. It is necessary actually to compare the depth of surface soil with that in virgin areas in order to determine the amount of erosion. The fact that the loess in eroded areas is high in calcium, phosphorus, potash and other minerals, adds to the general impression of little erosion. One or two crops of sweet clover often will return enough organic matter and nitrogen to bring the eroded area back to a productive condition.

Agricultural Practices in Relation to Soil Erosion

As has been indicated in the previous discussion, little attention has been given to the control of erosion in this soil area primarily because of three facts: (1) The surface soil has washed away practically unnoticed; (2) the original surface soil was extremely deep and much erosion could take place before it was all gone; and (3) even the subsoil loess is comparatively fertile and with the addition of organic matter—sweet clover as green manure, or other forms of organic matter—the soil is readily made productive.

Because the soils of this area are well drained, possess good tilth and are extremely productive, they have been subjected to an intensive system of farming. A larger percentage of the land in this area is devoted to corn production than in any other area in the state. Apparently no systematic crop rotation is followed in many parts of the area, legume crops are grown infrequently, and on many farms corn is grown on the same fields year after year. Furthermore, corn and other inter-tilled crops have often been planted in rows running up and down the slopes. After cultivation the small furrows left between the rows serve as channels for runoff water, and water running down moderately long slopes has strong soil-cutting and transporting power. As a result, in many fields a small gully forms in each

furrow after a heavy rain. This condition is most noticeable in old corn fields in the spring before the land is plowed, but it may be observed after any rain heavy enough to cause appreciable runoff. This practice of growing inter-tilled crops year after year and of planting the corn in rows and cultivating up and down the slopes, which leaves small furrows that serve as water channels, has greatly increased soil erosion in the Missouri loess area. Furthermore, practically no grassed waterways have been left in the natural drainageways of the Marshall silt loam. This has resulted in the more rapid cutting of the soil and the development of extremely deep gullies. If such farm practices are followed in the future, soil erosion will proceed much more rapidly than in the past. Obviously, this will result in the loss of most of the surface soil over a large part of the area, and only the subsoil will remain for crop production. Much may be done to correct this situation by following a good system of soil management, by practicing strip cropping and contour farming on the strongly rolling lands and by providing a good vegetative cover of grass in the natural run-off channels. These and other measures of erosion control are discussed under the heading of Erosion Control Measures.

The Southern Iowa Loess Soil Area

The Southern Iowa loess soil area comprises that portion of the state from the eastern boundary of the Missouri loess area in Adams and Taylor counties east to within a short distance of the Missisippi River and includes practically all of the southern three tiers of counties within these bounds. Originally this area was covered by the debris of the Kansan glacier and to a limited extent by the Nebraskan glacier and later by a layer of loessial material averaging between 15 and 25 feet in thickness. Erosion has occurred to a considerable extent since this loessial material was laid down and now the area presents a picture of a more or less completely dissected loessial plain. The general direction of the drainage is to the southeast, and it is good to excessive.

Soils of the Southern Iowa Loess Area

There is a distinct relationship between the topography and the soil types in this area. One of the principal soils of the area is the *Grundy silt loam*

Fig. 11. Sheet erosion occurs extensively on the Marshall silt loam; numerous small rills and miniature gullies are formed during periods of heavy rainfall. These disappear when the land is cultivated and the more apparent evidences of erosion are destroyed. In the meantime, however, the fertile surface soil is being washed away.

which occurs on the level to gently undulating uplands. It is of loessial origin, dark brown to black in color and from 12 to 16 inches deep. Below this point the material becomes heavier and less friable until at about 24 inches it is a heavy silty clay. This soil is very productive when properly managed. In general, owing to the level topography, it is not eroded badly, but on the edges of the type where gullies from the drainageways have extended into the uplands there has been some erosion.

The *Grundy silty clay loam* covers areas of appreciable size in the eastern part of this loess area. This soil is similar to the Grundy silt loam except that it is flatter in topography and is more in need of drainage. Although it may be erodible in its physical and chemical characteristics, it has not been eroded because of its flat topography.

Other upland loessial soils of this area are the *Putnam, Edina* and *Marion silt loams.* These soils do not cover any large area, and, because of their flat to level topography, they do not present an erosion problem.

The rougher uplands adjacent to the streams are largely covered by the *Clinton silt loam,* a loessial soil, and by the *Shelby loam* and *Lindley loam* which are of drift origin. These soils are all highly erodible.

The *Clinton silt loam* occurs chiefly in the eastern third of the Southern Iowa loess area where it covers extensive areas of the upland. The surface soil of the Clinton silt loam is a gray to grayish-brown, smooth, floury, uniform silt loam extending to a depth of 8 to 10 inches in the virgin state. Below the surface soil there is a buff to yellow or yellowish-brown, friable silt loam more compact than the surface soil and containing more clay. Below 14 to 20 inches the subsoil consists of a heavy, compact, tough, buff, brown or yellowish-brown to gray and brown silty clay loam. In topography it is rolling to hilly and generally the rougher and steeper slopes adjacent to the streams face the north. The slopes range from 5 to 15 percent or steeper, with the average being, perhaps, about 10 percent or slightly above. This soil has been developed under forest conditions, and much of it is still covered with native timber. In areas where the timber has been cut, however, and especially on the steeper slopes, it has been eroded badly. A large part of the surface soil has been removed by erosion, and gullying has become so severe that many fields have been completely ruined.

The *Shelby loam* is of glacial origin and occurs where erosion has been carried to the point where the loessial covering has been completely removed. It has an appreciable amount of sandy material intermixed with the silt and clay. The surface soil is a dark brown to black granular loam to a depth of about 10 inches. It is underlaid by a dark brown or brown coarse granular heavy clay loam extending to an average depth of about 21 inches. Below this point there is a layer of heavy clay loam or sandy clay containing some pebbles and gravel.

The Shelby soil is the most extensively developed drift soil in the Southern Iowa loess area, and it occurs chiefly in the western two-thirds of the area. Approximately 44.6 percent of Union County is covered by this soil, while it comprises only about 4 percent of the area of Jefferson County which is in the eastern part of the area where the Clinton silt loam predominates. In topography, it is rolling to hilly and the slopes range from 5 to 15 percent or more and average about 8 to 10 percent.

This soil is fairly productive where it has been properly managed and erosion has been controlled. Owing to its physical properties and topography, however, it may be rated as one of the most erodible soils of the state. Where it has been cultivated much of the surface soil has been washed away and there has been severe to excessive gullying. Many fields have been completely ruined.

Fig. 12. Characteristically deep gullies that are comparatively narrow at the top and have almost vertical sides form in the natural drainageways in the Marshall silt loam when the land is farmed without regard to proper soil management and erosion control.

The *Lindley loam* is also of glacial origin, but in many places it has a thin covering of loessial material over the drift. It is a minor type in the area from the standpoint of acreage, but it is of considerable importance from the standpoint of erosion. This soil has been developed under forest conditions, hence, it is lighter in color than the Shelby soil and is somewhat less productive.

Fig. 13. Typical gully formation in the Southern Iowa loess area. In this area the gullies do not cut so deeply as in the Marshall silt loam, but they form numerous finger-like tributaries into the hillsides and adjoining uplands which rapidly destroy the land for agricultural purposes.

The surface of the Lindley loam to a depth of about 4 inches is a gray, friable, somewhat floury loam or very fine sandy loam. Below 4 inches it is a grayish-yellow, heavy loam or silt loam. It usually occurs on the steeper slopes adjacent to streams. The slopes range from 10 to 25 or 30 percent or more. Hence, it is subject to severe to excessive erosion.

Much of this soil is still covered with virgin timber or is being kept in permanent pasture. Where timber is still standing the erosion has not been especially severe, but where the timber has been removed and the land cultivated erosion has removed much of the surface soil and has formed gullies to the point where it is impossible to continue cultivation in many fields.

Topography and Degree of Slope

Slopes have been discussed partially in the descriptions of the various soils. In general, however, the slopes upon which these soils occur are as follows:

Grundy silty clay loam	0- 1 per cent
Grundy silt loam	0- 5 per cent
Putnam silt loam	0- 3 per cent
Edina silt loam	0- 3 per cent
Marion silt loam	0- 5 per cent
Clinton silt loam	5-20 per cent
Shelby loam	5-20 per cent
Lindley loam	10-30 per cent

Type and Extent of Soil Erosion

Soil erosion in the Southern Iowa loess area has proceeded more extensively and reached the point where more land is completely ruined or will be ruined in the near future than in any other soil area.

On a percentage basis it may be estimated that more of the surface soil has been lost from the Marshall silt loam of the Missouri loess area than from the eroded soils of the Southern Iowa loess, but such an estimation does not show directly the amount of soil left for future crop production. The Marshall silt loam was unusually deep in the virgin condition, and although 75 percent of it may be gone in some areas, there still remains 4 inches or more of very productive soil which may be as much as some of the Southern Iowa soils had in the beginning. Assuming that the Shelby loam was 10 inches deep in the surface soil originally and that 75 percent of it has been washed away, there would be only 2½ inches of surface soil remaining for crop production in the future. And that is exactly the situation in many fields.

Aside from the Grundy and related soils that occur on the level uplands, the Southern Iowa soils were not deep in their original state, and over most of the area of the Shelby, Lindley and Clinton soils where they have been cultivated, erosion has carried away 50 to 75 percent, or in many fields more, of the surface soil. Consequently, the loss of surface soil in this area is a very serious handicap to a profitable agriculture.

Fig. 14. Leaving the soil bare of vegetation greatly accelerates soil erosion. Slopes too steep for cultivation should be planted to grass or reforested.

Furthermore, gullies have developed severely on the slopes, and are rapidly working their way into the better upland soils. Unlike the soils of the Missouri loess area, where the gullies only follow the main drainageways, these soils gully badly on practically all the hillsides, and each gully develops numerous finger-like branches into the uplands. In general, the gullies are not as deep as those of the Missouri loess area, but they are more numerous and injurious. Many fields of 20, 40, or even 80 acres in size were observed to be so completely dissected with gullies that they could no longer be cultivated and the land has been abandoned, and most farms have small areas that have thus been ruined for cultivation.

Agricultural Practices in Relation to Soil Erosion

The type of agriculture followed in this soil area has been most conducive to soil erosion. Originally much of the area was in timber. The first settlements were along the streams and in the rougher and timbered sections. Hence, the timbered lands were cleared and farmed first and the prairie land later. Furthermore, this portion of the state was the first settled and so has been farmed longer than any other section.

It seems to have been the practice in this area to clear the timber from a little more land each year to replace that previously cleared and which has become less productive as a result of continued cultivation and erosion. This practice is still being followed. The remaining timber land, however, occurs on the steeper slopes, and it would be disastrous to have it cleared. It seems that some concerted effort should be made to prevent the further clearing of this land. For example, there is an area of approximately 6,000 acres of timbered Lindley loam bordering the White Breast Creek in the southeastern part of Clarke County which shows the value of maintaining the stand of timber. The slopes of this soil range from about 10 to 15 percent. In the areas adjacent, erosion has carried away a large percentage of the surface soil, and gullying has been excessive, but in this forested area the soil has been maintained almost in its original condition. Such areas should be preserved and protected from erosion. There are many other such areas, most of them smaller in size. Preserving them would do much to protect the adjacent upland soils from erosion.

In general, although the slopes are steeper in the eastern half of this area, the erosion has been most severe in the western half. This is undoubtedly because it has been easier to cultivate the less steep slopes, and as a result they have been subjected to a more intensive system of farming, which has been more conducive to erosion. In going over the area from west to east this condition is rather noticeable. In Ringgold, Union, Decatur, Clarke, Wayne and Lucas counties the slopes are not so steep as in the counties to the east. There is also a smaller acreage of pasture and more corn, and erosion has been more severe. From Appanoose County east the slopes, in general, are steeper and more of the land has been kept in permanent pasture. This was done largely to retard erosion, so that, in general, more of the surface soil is left, and the gullies are not so numerous nor have they been so injurious in their action.

Aside from the foregoing, very little is being done to prevent or control soil erosion in this area. The situation calls for immediate concerted action to save this area from ruination and abandonment of thousands of acres of productive land.

The Mississippi Loess Soil Area

The Mississippi loess soil area occurs in the eastern part of the state in the counties bordering the Mississippi River and parts of adjacent counties. It extends westward into the central part of the state as far west as the Missouri loess soil area between the Southern Iowa loess area on the south and the drift areas on the north. The exact location of the area is shown in fig. 9. All of this area except that portion in the northeast corner of the state from Jackson County north to the state line was once covered with glacial till of either the Kansan, Iowan or Wisconsin glaciation. Later a layer of loessial material was deposited over the entire area, including the unglaciated section. The depth of the original loess varied considerably. Furthermore, there has been considerable erosion since the deposition of the loess mantle. As a result, there is now much variation in the topography of the area.

Soils of the Mississippi Loess Area

The principal soils of the area are the Clinton, Tama, Muscatine and Fayette silt loams which are of loessial origin. In the northeast unglaciated section, there is a considerable area of residual soils and some rough stony land. The principal residual soils are the Sogn and Gasconade loams. The Dodgeville silt loam, a loessial soil usually having lime rock within the surface 36 inches, also occurs in many small areas in the unglaciated portion of this soil area.

The *Clinton silt loam* occurs principally in the counties adjacent to or near the Mississippi River. It has been developed under forest conditions and is usually rolling to steep in topography. A complete description of this soil was given under the discussion of the Southern Iowa loess soil area. This soil occurs in both areas.

The *Tama silt loam* probably covers more of this soil area than any other type, and it is considered one of the better soils of the state. While it occurs intermixed with the Clinton silt loam in the counties adjacent to the Mississippi River, it is developed most extensively in the central part of the state. In topography, it is gently rolling to rolling and in some sections rather sharply rolling.

The surface soil is a dark brown to almost black friable silt loam, 10 to 12 inches in depth. This is underlaid by a dark brown to brown heavy silt loam or clay loam. The subsoil at about 20 inches is a brown or yellowish-brown friable silty clay loam.

Practically all of the Tama silt loam is under cultivation. Corn, oats and clover are the chief crops grown, and the soil is naturally very productive.

This soil is not as erodible as many of the other loessial soils of the state, such as the Marshall and Grundy soils, that are otherwise similar in many respects. It is also considerably less erodible than the Shelby and Lindley and Clinton soils of the Southern Iowa loess area.

The *Muscatine silt loam* occurs in the level to depressed areas adjacent to the Tama silt loam. It is somewhat similar to the Tama silt loam, except that it has developed under conditions of poor drainage and, hence, is darker and deeper in the surface and the subsoil is a drab or slate-colored silty clay loam. When well drained and properly managed, this soil is very productive and may be intensively farmed without danger of erosion.

In general, the individual areas of this soil are comparatively small except in the southeast portion of the soil area, principally in Muscatine and adjacent counties, where rather extensive areas are developed.

The *Fayette silt loam* is somewhat similar to the Clinton silt loam and occurs principally in the northeast portion of the soil area. In Clayton County, for example, this soil covers over 28 percent of the total area.

The surface soil of the Fayette silt loam to a

Fig. 15. The planting of crops on the contour reduces rainfall runoff and erosion. Each crop row serves as a miniature terrace to hold the water.

depth of about 5 inches is a grayish-brown or yellowish-brown smooth friable silt loam, which when dry appears gray. The subsoil to about 18 to 20 inches is yellowish-brown, and differs little in texture or structure from the surface soil. In topography this soil varies from rolling to strongly rolling or steep. It occurs on slopes and rolling areas, being found on the steeper slopes and along the narrow ridges. The degree of slope for the soil ranges from about 5 to 20 percent with an average between 10 and 15 percent. From the standpoint of erodibility it may be classed as being intermediate between the Clinton and Tama soils, but because of the general type of farming which has been practiced on the Fayette soils erosion has not proceeded to the same extent as on the Clinton soils. Considerable care is required, however, in handling this soil to prevent erosion.

About 30 percent of the area of Fayette silt loam is under cultivation. The remainder is covered largely with timber, or, where the timber has been cleared, it is used for permanent pasture. When properly managed this soil is very productive.

The *residual soils,* such as the *Sogn, Gasconade, Union* and *Dodgeville,* and small areas of *rough stony land* which are made up of a mixture of the various residual soils, occur rather extensively in the northeast portion of the area, chiefly from Jackson County north to the state line. This land is somewhat rough and broken in topography, the degree of slope being as much as 30 to 40 percent on some hillsides. Furthermore, outcroppings of limestone and some sandstone are common in this section.

The rough stony land is largely non-agricultural and is of little value except for grazing, while the other residual soils are generally cultivated.

Topography and Degree of Slope

The general topography of these soils has been discussed but more specifically the degree of slope for the various types have the following ranges:

Muscatine silt loam	0- 3 per cent
Tama silt loam	3-10 per cent
Fayette silt loam	10-20 per cent
Clinton silt loam	5-15 per cent
Residual soils	5-15 per cent
Rough stony land	10-50 per cent

Type and Extent of Soil Erosion

The Muscatine silt loam, in general, does not present an erosion problem. The Tama silt loam may be rated as of only medium erodibility, and although it occurs on slopes ranging from 3 to 10 percent, it has not been eroded as badly as the Clinton, Shelby, Lindley and Marshall soils. Most of the Tama silt loam has lost between 25 and 50 percent of the surface soil, however, and in many small areas there has been an even greater loss of surface soil. Gullies have formed in most of the natural drainageways, and they have also worked their way into the hillsides on many farms. Unless measures are taken to check their further development, gullies will undoubtedly ruin many fields. Although this soil is not eroded as badly as many others in the state, it is undergoing active erosion.

A real erosion problem is encountered in practically every section where the Clinton silt loam occurs. This soil is highly erodible, and wherever the native timber has been removed and the land cultivated there has been severe erosion. In general, the soil is fairly productive and is easy to till. Consequently, it has been intensively cropped in most places, which has done much to increase erosion.

Fig. 16. The contour planting and cultivation of corn where it is listed proves helpful in erosion control. Water is held between furrows instead of being permitted to run down hill and form gullies in the furrows as is so often the case when corn is listed up and down the slopes.

Numerous examples of severe sheet and gully erosion were observed on this soil. In many fields it was found that the surface soil had been completely washed away, and the yellowish subsoil is also washing away. This enormous loss of surface soil has been accompanied by the rapid development of gullies that are working their way into the hillsides from the natural drainageways.

Erosion of this soil, in general, is very serious, and control methods should be adopted as quickly as possible.

The *Fayette silt loam* presents a little different erosion problem. Although it occurs on rather steep slopes and also in a region where heavy rainfalls are not uncommon, it has not been seriously eroded. This is primarily because the farmers who cultivate it have adopted soil management practices that have done much to control erosion. It is likely, however, that unless erosion control is continued on this soil and given even more consideration on many farms, the land will be ruined very rapidly.

Fig. 17. The washing of soil down the corn rows has caused large losses of surface soil on the rolling lands of Iowa.

There was considerable erosion in past ages in the residual soils and the rough stony land areas before the land was settled with the result that the loessial material had largely been washed away, exposing the underlying limestone or sandstone rock. In most places where the original rock is not exposed the surface soil is not deep and is intermixed, usually with fragments of limestone. Hence, there is not a large amount of surface soil being lost at present, nor is there an appreciable development of gullies. The area, however, calls for special attention to erosion control in order to preserve the small amount of surface soil that remains as the land is of much value for grazing purposes.

Agricultural Practices in Relation to Soil Erosion

The land of this area, in general, is subjected to a rather intensive system of agriculture which is conducive to soil erosion except in the northeast portion of the area. In the latter section the prevailing slopes are rather steep, being usually over 10 percent. The farmers of that section have been faced with the problem of severe erosion and they have become "erosion conscious." In general, they are following a better system of farming for soil maintenance than those in the other parts of the Mississippi loess area. They have followed a dairy system of farming, using much of the land for the production of forage and for grazing. They grow legumes on an appreciable portion of their land each year and, in general, grow corn for not more than 1 year in the rotation on most of the land. Furthermore, many farmers have practiced strip cropping, contour farming and in some instances terracing. Their methods for preventing gully erosion are rather noticeable. In the swales where gullies would naturally develop, the land is never plowed in most fields. In the plowing operation, the plow is lifted from the ground and allowed to pass over the surface when crossing the natural drainageways. These strips are kept seeded down to the native prairie and timber grasses, which with their abundant top growth and extensive root systems are very efficient in controlling erosion.

The farmers of other sections of the state could well learn something about erosion control from those of this section. From outward appearances the farmers of this section are comparatively prosperous. On practically every farm there is a good home, good farm buildings and a large dairy barn that indicate the type of agriculture followed and the general prosperity.

The soils of the southeastern part of the Mississippi loess area, chiefly the Clinton silt loam, are badly eroded, largely as a result of the type of farming that has been followed. The Clinton silt loam was originally covered with timber. Because of the steep slopes upon which most of this soil occurs and its highly erodible character, much of it should never have been cleared of timber, and many sections should undoubtedly be placed under a good system of forest management. Where the timber has been cleared, the land is cultivated intensively. Frequently corn is grown year after year on the same land. Corn and soybeans are planted in rows up and down the slopes, and the furrows left after cultivation serve as channels down which runoff water carries large amounts of surface soil. In these channels numerous small gullies form each year. Furthermore, little or nothing of an effective nature is being done to prevent or control erosion on this soil.

In the Tama and Muscatine silt loam soils a very intensive type of farming is followed because they are easily tillable and normally highly productive. In the sections of more strongly rolling topography and on the steeper slopes where the Tama silt loam predominates, the intensive farming has been conducive to severe sheet erosion. Hence, in these places between 25 and 50 percent of the surface soil has washed away.

The Iowan Drift Soil Area

The Iowan drift soil area is located in the northeastern part of the state. It is bordered on the south and east by the Mississippi loess area and on the west by the Wisconsin drift area. The area consists of an undulating drift-covered plain which is cut by a series of rivers and small streams which flow from northwest to southeast.

Most of the streams have their headwaters in the northern part of the area where the general topography is that of a level to gently undulating plain. Toward the southeastern portion of the area the streams have cut rather deeply into the drift, and in many places the underlying limestone appears near or at the surface. Hilly areas of a mile or more in width often occur along the larger streams in the southern part of the area. Between the various streams, the smooth uplands have a rather gentle undulating topography.

Soils of the Iowan Drift Area

Drift soils cover from 75 to 80 percent of the total area in this part of the state. Terrace, swamp and bottomlands cover the remainder of the area. The principal drift soils are those of the Carrington, Dickinson, Clyde and Floyd series. Small isolated areas of Lindley soils also occur. The terrace and bottomland soils belong to the O'Neill, Bremer, Wabash and Cass series.

The *Carrington loam* and *Carrington silt loam* are the principal soils of the area, and they occur on level or undulating upland plains. These soils are broken by finger-like stretches of Floyd and Clyde soils which follow the poorly-defined drainageways into the upland plains.

The surface soil of the Carrington loam is a finely granular dark grayish-brown, friable loam. It is underlain at a depth of about 12 inches by a dark grayish-brown loam containing much fine sand. Between the depth of 12 and 24 inches the color changes from a very dark grayish-brown to a brown. The texture ranges from a loam in the upper part of the layer to a heavy loam or silty clay loam in the lower part. The subsoil changes from a light brown, heavy silt loam to a yellowish-brown clay loam, streaked with gray and containing coarse sand and small pebbles.

Practically all of the Carrington loam is under cultivation and its natural fertility is high.

The *Carrington silt loam* is very similar to the loam except that it has more silt and less sand in the surface soil.

The *Clyde soils* occur in the poorly-drained depressions and are used mainly for pasture.

The *Floyd soils* are intermediate between the Carrington and Clyde and are used more for cultivated crops than for pasture where the land has been adequately drained.

The *Dickinson fine sandy loam* occurs in numerous areas which range in size from a few acres to a square mile. Within areas of the Carrington soils the type occurs on knolls which are several feet higher than the surrounding plains. It also occurs on slopes adjacent to the minor streams or drainage channels. This soil has a thin surface covering of dark grayish-brown, fine sandy loam. The subsoil is also a sandy loam, but is lighter in color. Because of its characteristic strongly rolling topography the soil is subject to some sheet erosion during heavy rains. Practically all of the type is cultivated or used as hay land.

Fig. 18. Large amounts of fertile surface soil are washed away in the small rills and gullies that develop on land left bare and exposed to the erosive action of run-off water. A good vegetative cover will practically prevent this type of soil erosion.

Fig. 19. Corn washed out and gullies formed in the wheel track of the corn planter as a result of heavy rains and of planting the corn up and down the slope instead of around the slope on the contour.

Topography and Degree of Slope

The prevailing slopes in this soil area range from 0 to 5 percent and in the northern counties of the area few slopes are steeper than 3 percent. In the southern portion of the area the topography is more strongly rolling, and many of the slopes are steeper than 5 percent. The terrace and bottomland soils are practically flat in topography, hence, the slopes are less than 3 percent.

Type and Extent of Soil Erosion

This area is characterized in general as one of slight erosion. Undoubtedly some surface soil has washed away from most of the Carrington soils, but in the main this would amount to less than 25 percent. There are numerous areas of the Carrington soils, although small in extent, that are slightly more rolling than the major portion of this type. Although these areas are usually a little coarser in texture, they have been eroded to a greater extent than the surrounding soils, primarily because of the steeper slopes. From 25 to 50 percent or more of the surface soil has been washed away in these more rolling areas. Likewise, there has been an appreciable amount of erosion on the steeper slopes of the Dickinson soils, where 25 to 50 percent of the surface soil has been washed away in many places.

Fortunately, the areas subject to severe erosion are rather small and widely scattered in this part of the state, so that erosion is not a serious problem in this soil area. By proper soil management, with special attention to the more strongly rolling phases of the Carrington and Dickinson series, the little erosion that does occur can probably be controlled without great difficulty.

Few gullies occur in this soil area, and they are in the main drainageways in the more strongly rolling sections adjacent to the streams. In the northern part of the area gullies are comparatively rare.

Agricultural Practices in Relation to Erosion

An intensive system of agriculture is being practiced in this area and little or nothing is being done to prevent the loss of soil from the more strongly rolling phases of the Carrington and Dickinson soils. Better balanced cropping systems and good soil management practices would do much to control erosion.

The Wisconsin Drift Soil Area

The Wisconsin drift soil area is located in the northwestern central part of the state. It is bordered on the west by the Missouri loess, on the south and southeast by the Mississippi loess and on the northeast by the Iowan drift. The Wisconsin glacier was the last to cover the state, hence, there has been less time for erosion to modify the topography of the area and for the soil-forming processes to act. The result is a level to gently undulating plain, dissected to only a slight extent by streams, and having relatively immature soils and, in general, only slight erosion. The three principal streams of the area are the Iowa, Des Moines and Raccoon rivers. In general, the Iowa River has not cut deeply into the area and there is little rough land adjacent to it north of Hardin County. Through

Hardin County and south, however, it has cut completely through the glacial drift and in many places has developed a rather deep gorge into the native limestone rock.

North of Fort Dodge the Des Moines River has not cut deeply, but from there south to the boundary of the drift area this river has cut an extremely deep gorge through the drift and bedrock. As a result there has been considerable erosion in the soils adjacent to the river.

The Raccoon River which crosses the southwest portion of the area has a rather wide flood plain. The slopes adjoining the river are steep, however, and they are badly eroded for a short distance from the stream. In only a few places are the broken areas more than 1 mile wide.

Soils of the Wisconsin Drift Area

The principal soils of this area are those of the Clarion and Webster series. In addition there are appreciable areas of Dickinson, Pierce, O'Neill, Waukesha and Wabash soils and peat and muck. In Kossuth County, for example, the Clarion loam constitutes 40.1 percent and the Webster loam and silty clay loam constitute 51.4 percent of the total area.

The *Webster soils* occur on the broad, flat, smooth plains, and in the depressions and swales where drainage is poor. This soil is very black in the surface and because of its immaturity the horizons are not well defined. The surface soil is rather deep, however, gradually becoming heavier in texture. The subsoil from about 28 inches is a silty clay loam, grayish-yellow or gray and mottled. Small glacial boulders and pebbles occur at all depths. It is also high in lime. Due to its topography and physical properties this soil may be rated as comparatively non-erodible.

The *Clarion soils* occur in the more gently rolling to rolling upland portions of the Wisconsin drift area. The surface soil of the Clarion loam is dark grayish-brown loam which appears black when wet. The depth of the surface soil is from 7 to 10 inches. The subsurface to a depth of about 24 inches is a very dark grayish-brown, rather heavy loam. The subsoil is a grayish-yellow, mellow glacial drift composed chiefly of clay, but it contains some sand and a few pebbles of various sizes. The subsoil is usually highly calcareous.

In numerous places this soil and other types of the series, principally the fine sandy loam, occur as low rounded knobs or ridges. The material of these soils is probably of morainic origin or it was deposited by the glacier as kames. In these places the surface soil is thin, and there is evidence that much of it has been washed away. The slopes on these areas vary from 3 to 10 percent or more, and in most cases the slope is the chief factor governing the extent of erosion.

The *rolling and steep phases of the Clarion loam* do not cover an extensive acreage in the area, but they are of considerable importance from the standpoint of erosion. The soils occur along the slopes bordering the rivers and streams, the steep phase occurring on the bluffs and steeper slopes. The latter type is too steep for cultivation and is largely forested, whereas the rolling phase is not so steep and is used more for pasture. Erosion is severe on these soils. Although the surface soil was not deep originally, sheet erosion has washed away a large part of it, and in many places the yellow subsoil is exposed. Excessive gullying is also evident in this type, due largely to the prevailing topography.

The *Dickinson* and *Pierce* soils occur within areas of the Webster and Clarion soils. They are usually a little more rolling in topography and coarser in texture. The Pierce soils especially are composed of a heterogeneous mixture of glacial material, including much sand, gravel and boulders. Principally because of the character of the glacial material and the topography, these soils have never developed a deep surface, and there has been considerable sheet erosion.

Topography and Degree of Slope

In general the prevailing slopes of this area range from 0 to 5 percent, with much of the land, chiefly the Webster soils, having slopes less than 3 percent. Slopes on some of the Clarion soils in the morainic areas range from 5 to 10 percent. Comparatively steep slopes occur in the Clarion loam (steep phase) along the rivers in the southern part of the area, ranging from 5 to 30 percent.

Type and Extent of Soil Erosion

There has been only slight water erosion on the Webster soils and on the more gently undulating areas of the Clarion soils. Less than 25 percent of the surface soil has washed away, and extremely few gullies have formed.

On the more rolling areas of the Clarion and in the morainic regions where the slopes in some places are as steep as 10 percent, there has been more erosion. Twenty-five percent or more of the surface soil has been washed away from many of the slopes.

Gullies, however, have not developed except in isolated cases.

During the spring months when the land is bare and when the rainfall is rather heavy the exposed slopes on the Clarion and Dickinson soils are subject to severe erosion. The more apparent effects of this erosion are largely obliterated in subsequent cultivation of the land, but the exposure of the lighter colored subsoils, the decreased water absorptive capacity and the low fertility of these areas are becoming more prominent from year to year.

On the steep slopes of the Clarion loam bordering the rivers there has been excessive sheet and gully erosion. In these areas 50 to 75 percent or more of the surface soil has been washed away. In most places the situation is serious and necessitates immediate attention to prevent the further development of gullies into the adjacent uplands and further loss of surface soil.

As a result of the prevailing topography and type of farming practiced in this area, there is, in some years, an appreciable amount of soil erosion resulting from wind action. Strong winds blowing over large areas of comparatively flat land with occasional slopes in the spring when the land is unprotected with a vegetative cover, and when there has been less than the normal amount of rainfall, carry away large amounts of the fertile surface soil. Aside from carrying away the surface soil, an enormous acreage of crops is frequently ruined by the strong cutting action of the dust carried by the wind. Other damaging effects of the wind erosion are the drifting of soil in roadways, along fence lines, around farm buildings and in other places where it may cause damage or inconvenience. This wind erosion can be largely checked by a proper cropping system which in many cases should include the growing of a winter cover crop of rye, barley or some other crop that will cover the land in affected areas during the late winter and spring months when this type of erosion is most likely to occur. Special cultivation practices in affected areas should also be adopted. These are described in the section dealing with the control of soil erosion.

Agricultural Practices in Relation to Erosion

A very intensive system of farming with the production of corn and small grain is followed in this soil area. This is naturally conducive to erosion on the steeper slopes where the soils are subject to erosion. Better planned cropping systems and soil management practices will do much to prevent further erosion in this area.

On the steeper slopes adjacent to the larger rivers, much of the land is in timber. In many places, however, the timber is being cut down and the land cleared, even though it is too steep for cultivation.

THE CONTROL OF SOIL EROSION IN IOWA

Nature has undoubtedly demonstrated the ideal method of controlling soil erosion. An abundance of grass grew on the rolling prairie lands, and grass, brush and timber were produced on the rougher lands bordering the streams. Obviously it would not be profitable nor desirable to leave all the land under these types of vegetation, and a large part of it must be used for the production of cultivated crops. The erosion control method used by nature, however, may well be set up as an ideal, and the principles involved should be made a part of the soil management practices in present-day farming.

In order to control soil erosion in farm practice it would be wise to imitate nature and grow non-tilled and pasture crops on the land, refor-

Fig. 20. Terraces prevent large amounts of water from running straight down the slope at a high speed. Surface water is caught and led away slowly; thus the soil has more time to absorb moisture and danger of gully formation is greatly reduced.

est steep and broken areas, and build up the organic matter content of the soil. To do all these things and at the same time produce the necessary intertilled crops, it is essential: (1) To cultivate the soil properly and adapt the cultivation practices to the land according to the needs for erosion control; (2) to follow a well-planned crop rotation that is adapted to the type of soil; (3) to apply limestone to acid soils in order that legume crops may be grown in the rotation; (4) to plow under crop residues, green manure crops and farmyard manure; and (5) to apply phosphate and other fertilizers to soils that are deficient in these constituents in order to obtain larger acre yields.

Cultivation

It is well known that thorough cultivation is essential for the best production of crops, but from the standpoint of soil erosion control it is equally important that the land be cultivated properly. Soil losses from corn fields have undoubtedly been increased greatly because of improper cultivation. The illustrations in figs. 11, 17, 18 and 19 show how soil may be washed away in small channels between the corn rows when the corn is cultivated up and down the slopes. This situation may be avoided to a large extent by *contour cultivation* and also by strip cropping which will be discussed later.

Contour cultivation is one of the simplest methods of soil erosion control applicable to Iowa. It involves the cultivation of the land on the contours with the slopes rather than up and down the slopes. At the Soil Erosion Experiment Station near Clarinda in Page County, the contour planting and cultivation of corn has been one of the most effective erosion control measures. It has been found[4] that this practice provides a water storage basin between rows sufficiently large to hold 1½ inches of rain under the particular slope and soil conditions where it was tested. Other experiments at the Clarinda Station[5] have shown that the Marshall silt loam will absorb water comparatively rapidly; the infiltration rates have been found to be approximately 1¼, ¾ and ½ inches of water for the first, second and third hours, respectively. Hence, this type of cultivation alone should give protection against as much as 2¾ inches of rain in 1 hour, 3½ inches in 2 hours, or 4 inches in 3 hours, on this particular soil. No rains of this size have occurred at the Clarinda Station, but one intensive rain, totalling 3.31 inches in 4 2/3 hours on Aug. 21, 1933, and occurring immediately after a slow 12-hour rain, produced no runoff.

Contour cultivation also has certain other advantages. The draft of implements along level rows on the contour with the slope is appreciably less than along rows up and down the slopes.

When the contour cultivation and strip cropping are practiced it is essential that water channels having a good vegetative cover be provided to carry away the runoff water following heavy rains. This is necessary for it is usually difficult or impracticable to run all rows, in the case of cultivated

Fig. 21. Terrace outlets are necessary to care for excess water from the terraces. These should be seeded to grass and fenced off from the remainder of the field for their protection.

[4]Progress Report, Investigations in Soil Erosion and Moisture Conservation at the Soil Erosion Experiment Station, Page County, Iowa. In press. U.S.D.A. Soil Conservation Service.

[5]G. W. Musgrave. The infiltration capacity of soils in relation to the control of surface runoff and erosion. Jour. Amer. Soc. Agron., **27**:336-345. 1935.

crops or to perform other cultivation practices, on the exact contour, and there may be some runoff which should be cared for in such a manner as to prevent gully formation.

The *basin-lister method* of planting is a new method of cultivation which promises to have merit in controlling soil erosion in corn fields and particularly in sections where listing is practiced. A new type of corn planter has been devised by the Iowa Agricultural Experiment Station which places a small dam in the listed rows between hills of corn; this provides in effect a series of basins having a capacity for impounding surface water sufficient to hold an inch or more of water, depending upon the adjustment of the machine and the soil conditions. Experiments are now being conducted to determine more definitely the effectiveness of this type of cultivation for erosion control.

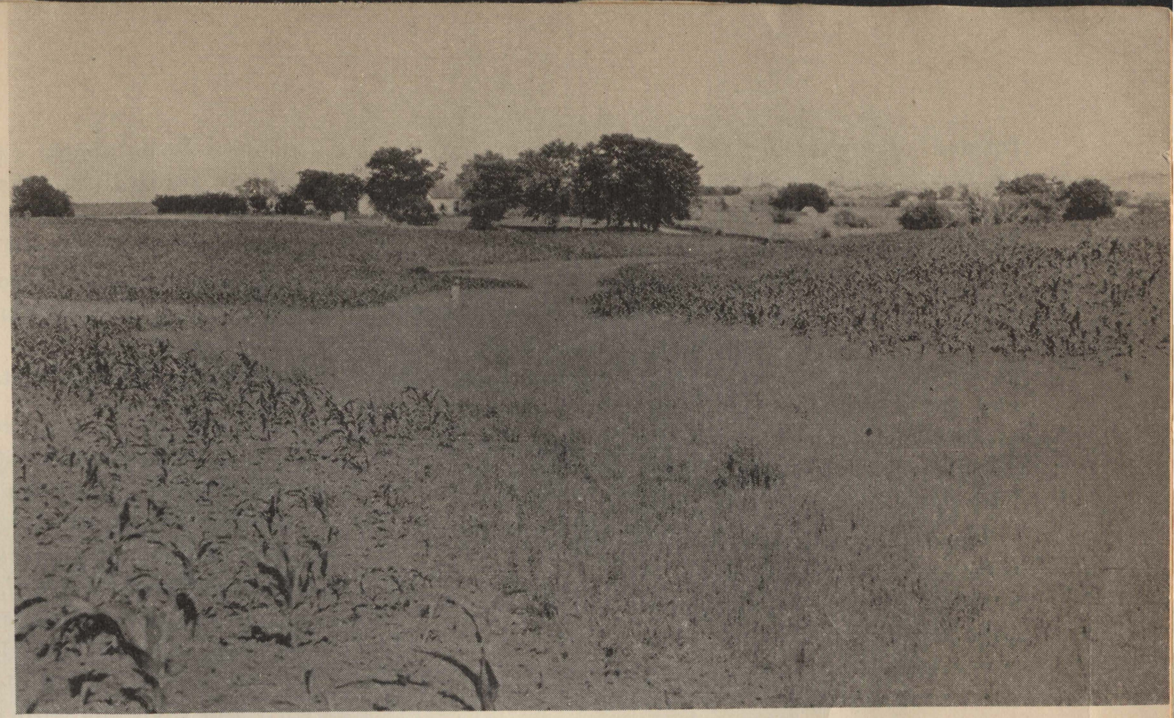

Fig. 22. Grass strips in the natural waterways do much to prevent gully formation and the carrying away of the surface soil. These strips should be rather wide and they should not be plowed.

Terracing[6] is also a form of soil cultivation that has been found effective in soil erosion control under certain conditions. A terrace as used in this country is a broad ridge with a shallow ditch on its upper side. The mechanical principle of the terrace is merely the diversion of the runoff water into channels of low gradient or slope around the hill rather than allowing it to flow directly down the natural slope of the land. Surface water above each terrace is caught and led slowly away in the terrace channel. This prevents large amounts of water from running straight down the hill at a high speed, where it may form gullies, and it also allows for a greater absorption of the water by the soil.

The type of terrace, the height, and the distance between terraces depend chiefly upon the type of soil being terraced, the degree of slope of the land, and the rainfall. Terraces are most easily maintained and cause the least inconvenience on moderate slopes. Land with slopes of 12 to 15 percent is usually considered the steepest that can be terraced and cultivated on a practical basis. The runoff water from the terrace should be controlled through a protected outlet until it is delivered to a natural and stabilized drainage channel. The terrace outlets should be seeded to grass and protected from damage by live stock, farm machinery or other agencies. Such a terrace outlet is pictured in fig. 21.

Grass strips in the natural drainageways will aid considerably in preventing the formation of gullies and the concentration of run-off water. When a field is being plowed, the plow should be lifted from the ground while passing over the natural drainageways in order that grass may grow there and that a good sod may form. Grassed waterways of this type should be rather wide in order to give complete control. The practice of plowing a furrow along the edge of this strip in order to trim it up should never be followed. This leaves a water channel on either side of the grass strip and encourages the formation of two gullies instead of one. An effective grass strip waterway is pictured in fig. 22.

Dams[7] are necessary when gullies have been

[6]See Extension Service Bulletin 172, "Terracing to Reduce Erosion." Also U.S.D.A. Farmers' Bulletin 1669, "Farm Terracing."

[7]The discussion under this topic has been condensed from Iowa Engineering Experiment Station Bulletin 121, "Recommendations for the Control and Reclamation of Gullies," by Quincy C. Ayres. For detailed information concerning the design and use of dams, the reader is referred to this bulletin, which may be obtained from the Engineering Experiment Station, Ames, Iowa. Bulletin No. 1234 of the U. S. Department of Agriculture also discusses in greater detail the use of dams in gully control and reclamation.

formed. By reducing the rate of flow of the run-off water, a dam reduces the soil-carrying and cutting power. Three types of dams may be employed: Temporary check dams, semi-permanent dams, and permanent or soil-saving dams.

Temporary check dams may be distinguished from the other types because they are usually built of inexpensive and temporary materials in medium and small gullies where dependence for ultimate protection is placed on vegetation or some kind of plant cover. The various types of brush and woven wire dams belong to this group.

The semi-permanent check dams, which may be constructed of loose rock, logs or planks, when properly constructed and maintained, have a reasonably long life and do not need supplementary vegetation for ultimate control to the same extent as do the temporary dams. On the other hand, they are more expensive to build and require a relatively large amount of materials.

Permanent dams, often referred to as soil-saving dams, find their principal use in medium and large gullies which drain watersheds of considerable size. Such dams are expected to catch and hold considerable quantities of soil and to prevent future losses without dependence on vegetation. The presence of vegetation behind a permanent dam, however, renders additional erosion protection.

The conditions governing the choice of structure to be used in any given case are: Cost, degree of dependence to be placed on vegetative cover, willingness to provide the necessary maintenance, and other physical, environmental and human factors. Structures of each type will give satisfactory service under their respective conditions if properly designed, installed and maintained.

Crop Rotation

The lack of proper crop rotations has accelerated soil erosion. Intensive systems of farming where inter-tilled crops are grown on the land repeatedly, (1) rapidly destroy the organic matter of the soil and thus reduce its water absorptive capacity and increase the rainfall runoff, and (2) leave the soil bare and exposed to the erosive action of runoff water much of the year. By properly rotating the crops and by alternating the inter-tilled crops such as corn and soybeans with non-tilled crops such as alfalfa, clover, timothy, other grasses and small grains, the land is exposed to erosion only about a third to a fourth as much of the time. The sowing of non-tilled crops frequently on the land is probably the most effective single step that can be taken to control soil and water losses from many areas. It is highly important, therefore, that such crops be included in the rotation.

Experiments on the Soil Erosion Experimental farms at Bethany, Mo., and near Clarinda in Page County, Iowa, have definitely demonstrated the effectiveness of the non-tilled crops in preventing soil and water losses, and the desirability of including these crops in the rotation. At Bethany, Mo., where the average annual rainfall is 33.99 inches, experiments conducted on the Shelby silt loam having a slope of 8 percent, which is typical of much of the land in the Southern Iowa loess area, show that when corn was grown on the land continuously, 24.1 percent of the rainfall ran off the land and carried with it 41.5 tons of soil per acre. On an adjoining plot where corn was grown in a 4-year rotation with wheat,

Fig. 23. Dams may be used to fill in gullies. They slow up the run-off water and allow the suspended soil to be deposited.

Fig 24. Percentage of effective farm land in inter-tilled crops—corn and soybeans. (1932)

clover and timothy, only 20.7 percent of the rain water ran off and it carried with it only 26.2 tons of soil per acre. Although the rotation of crops reduced the amount of runoff water only a little over 14 percent, the quantity of soil carried away with the water was reduced almost 37 percent. During the period of the rotation when wheat was grown on the land, the runoff was reduced to 19.0 percent, and the quantity of soil eroded was reduced to 9.9 tons per acre. A still greater reduction in runoff and erosion was effected by the mixed clover and timothy; it reduced the runoff to 9.9 percent of the rainfall, and the erosion was reduced to 2.7 tons per acre.

Similar results were obtained at Clarinda, Iowa, on the Marshall silt loam during the period from June 1, 1932, to December 31, 1934. On land where corn was grown continually, 8.7 inches of rain water ran off the land, carrying away 66.5 tons of soil per acre. On the land where a rotation had been followed the average runoff was only 6.2 inches of rain, and the average quantity of soil eroded was 27.9 tons per acre. This is a reduction of about 58 percent in the loss of soil by erosion as a result of following a suitable crop rotation. On the same soil type crops of alfalfa and bluegrass reduced the soil loss to 1.2 and 1.3 tons per acre, respectively. This is a reduction of about 98 percent in soil erosion when compared with that where corn is grown on the land continuously.

Figures 24, 25 and 26 show the general cropping practices that are being followed in the various parts of the state. It is significant to note that 50 percent or more of much of the effective crop land in western Iowa, where erosion is rather severe, is used for the production of inter-tilled crops. This percentage is too high for the permanent maintenance of the land in a high state of fertility. Furthermore, in other portions of the state the acreage of land in corn is too high to permit maintaining the fertility of the soil. This is true in many places, particularly in southern Iowa, where only 30 to 40 percent, or even less in some places, of the effective farm land is in inter-tilled crops. More non-tilled crops, the small grains and particularly the leguminous hay crops, should be substituted for a portion of the present corn acreage in putting into effect proper maintenance rotations on the erodible soils of the state.

In a recent study[5] on land use made by the Iowa Agricultural Experiment Station in cooperation with the Agricultural Adjustment Administration of the U. S. Department of Agriculture a comparison was made of the present cropping practices in Iowa and the systems that should be followed in order to prevent erosion and depletion of fertility. As a result of this study it was recommended that the average acreage of corn in the state be reduced approximately 19 percent, with different reduction percentages in different parts of the state depending upon the characteristics of the soils and the present cropping practices. It was also recommended that the acreage of pasture and non-tilled crops, particularly the leguminous hay crops, be increased proportionately. The recommended reductions in corn acreage for the various soil areas of the state are shown in table 7.

Although the average reduction figures are applicable to the various soil areas as a whole, they are not applicable directly on the individual farm. Because of particular characteristics of the soils on a certain farm, it may be desirable to reduce the acreage of inter-tilled crops to an even greater or a less extent than indicated by the figures. In general, the crop rotation system on each farm should be planned to meet the needs of the various soils for maintenance against erosion and depletion of fertility.

Strip cropping is a system of crop rotation that is effective in erosion control, and it may well be practiced in conjunction with contour cultivation. It involves the planting of alternate strips of non-tilled and inter-tilled crops. For example, at the Soil Erosion Experiment Station at Clarinda two strips of alfalfa, each 6 rods wide, are placed in

TABLE 7. RECOMMENDED CHANGES IN CORN ACREAGE FOR IOWA*

Soil area	Corn acreage 1929	Percent state total	Av. percent reduction recommended	Acreage recommended
Missouri Loess	3,319,524	30.05	23.70	2,532,797
Wisconsin Drift	2,742,976	24.83	13.64	2,368,834
Iowan Drift	1,441,737	13.05	10.54	1,289,778
So. Iowa Loess	1,598,303	14.47	24.60	1,205,120
Mississippi Loess	1,944,999	17.60	20.05	1,555,027
Total for state	11,047,539	100.00	19.00	8,951,556

*Since the completion of this work some revision has been made in the recommended changes in corn acreage. The recommended reduction in corn acreage is now somewhat less for the Mississippi Loess area and as a result the total change for the state has been reduced from 19 to 17 percent.

[5]Unpublished data, Iowa Agricultural Experiment Station, Project 363.

Fig. 25. Percentage of effective farm land in non-tilled crops—small grain and hay. (1932)

a 26-acre corn field at intervals so as to break the long slope and thus retard the flow of water and lessen the erosion. The corn is contoured and turn rows are provided on both sides of the field. The succession of crops gradually moves across the area as the rotation changes from year to year.

At the Soil Erosion Experiment Station at Bethany, Mo., alfalfa occupies the top contour strip 7 rods wide, corn is grown on the next parallel strip of equal width, clover on the next and oats occupy the strip at the bottom of the slope. Grass turnways are maintained at each end of the field. The strips are rotated so that a succession of crops gradually moves down the slope. Other rotation systems following this scheme of cultivation may be adapted to meet the needs of the individual soil types and conditions.

A combination of contour cultivation and strip cropping has been found to be very effective in controlling soil erosion, for it provides (1) the advantages of crop rotation and the benefits of non-tilled crops, and (2) to a certain extent, the mechanical advantages offered by terraces. Although this system of cultivation may appear impracticable to those who have not tried it, it is favored by most of those who have given it a fair trial. If the large losses of surface soil may be stopped in this way, any extra time and labor required would be entirely justifiable (fig. 27).

One of the chief advantages to be obtained from following a well-planned cropping system is the maintenance of soil fertility. The continuous production of a single crop on the land, and particularly inter-tilled crops, rapidly leads to impoverishment and infertility of the soil. Numerous experiments have definitely shown the desirability of practicing a desirable crop rotation on the land to keep up fertility.

A legume should be included in the cropping system. A well-nodulated legume crop may enrich the soil appreciably in nitrogen content through the activities of the root-nodule bacteria. Maximum amounts of nitrogen may be added when a good growth of the legume is plowed under to serve as green manure in the soil. Legumes such as soybeans, however, which have a very shallow root system, probably do not enrich the soil in nitrogen when all of the top growth is removed for hay, for practically all the nitrogen fixed by the root-nodule bacteria is removed from the land in the hay or seed. In the case of alfalfa or clover, however, the root system is deep and very extensive, and a large amount of organic matter and nitrogen is supplied the soil by the roots alone. In addition, however, when land growing these crops is plowed under considerable green material is turned under to enrich the soil in nitrogen and organic matter. For these reasons, it should not be considered that soybeans can replace deep-rooted alfalfa and clover crops in planning a cropping system for eroding land. In fact soybeans should never be sown where the soil is subject to appreciable erosion.

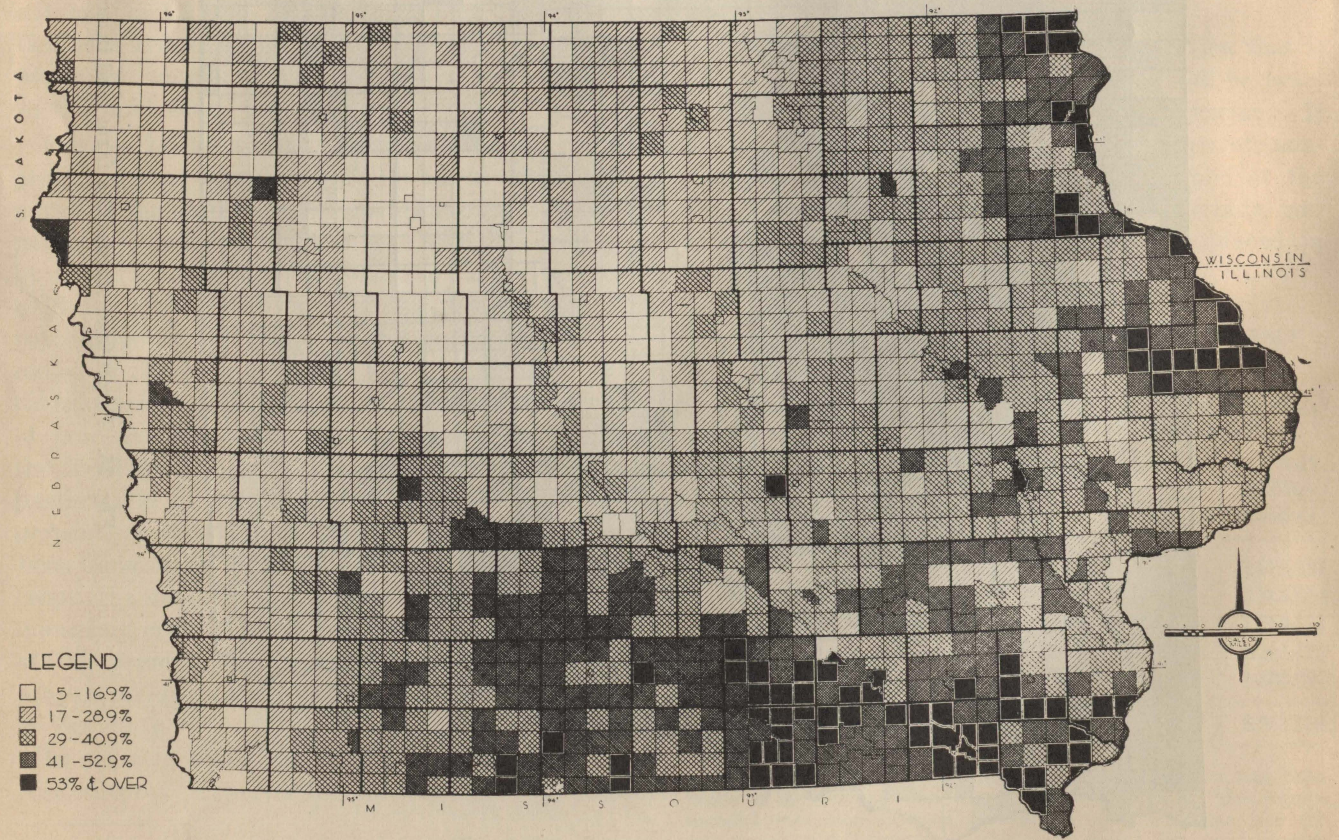

Fig. 26. Percentage of effective farm land in pasture. (1932)

When non-tilled legume crops are being sown on land subject to erosion, it is desirable to include timothy or other grasses because they have shallow, fibrous root systems which are very effective in protecting the soil against erosion, particularly the first year after the sod is broken up.

Another practice that has been found effective in controlling erosion on land cropped to inter-tilled crops is to seed a winter cover crop. During the fall, winter and spring months the land cropped to corn and soybeans is bare and unprotected from the erosive action of rain water. The use of rye or rye and vetch as a winter cover crop between corn crops has proved successful in tests over a 3-year period on the Marshall silt loam. Winter barley has also been found very satisfactory for this purpose in Southern Iowa. In addition to protecting the soil against water erosion during the fall, winter and spring these crops also prevent wind erosion. Furthermore, appreciable amounts of organic matter are added to the soil when the crop is plowed under, which increase the water absorptive and holding capacity and so aid in controlling erosion (fig. 28).

The most effective way of managing badly eroded land that cannot safely be used for cultivated crops is to seed it down to permanent pasture or plant trees on it. In the more extreme cases where the land is badly gullied the growing of trees may be desirable. Such areas when put into pasture should not be overgrazed for much of the effectiveness of a grass sod in erosion control is lost when the grass is pastured too closely. It is the top growth that is most effective in slowing up the runoff water and in reducing its soil-carrying power. The effectiveness of the pasture crop in controlling erosion may be greatly augmented by seeding a proper mixture of grasses and legumes to provide for an abundant growth of vegetation throughout the growing season.

Liming Acid Soils

It is difficult or impossible to establish the deep-rooted legume crops on acid soils without applying limestone to correct the acid condition. Furthermore, the legumes and other crops do not grow as well on acid soils as they do on soils where the acidity has been corrected by liming. Fully 75 percent of the soils of the state are acid, and these occur chiefly in the areas with the most erosion. From one to three or more tons of limestone per acre are needed on these soils.

Proper crop rotations—the most effective erosion control method—cannot be established without first correcting the acidity. Liming acid soils is the foundation of all sound soil management and erosion control practices.

Ground limestone is usually most economical. It should be applied in sufficient amounts to meet the lime requirements of the soil and should be thoroughly disced in. It should be applied preferably 6 months or longer before seeding the legume in order to allow sufficient time for correcting the acidity of the soil before the crop is sown. Limestone of high purity and ground sufficiently fine that all the material will pass a 10-mesh screen and 60 percent or more will pass a 40-mesh screen is most effective and desirable.

Plowing Under Crop Residues and Manures

It has been pointed out previously that the organic matter in the soil serves to facilitate the entrance of rain water and also increases its water absorptive capacity. Hence, soils containing large amounts of organic matter are less erodible than those deficient in organic matter. An experiment on the Marshall silt loam at the Soil Erosion Experiment Station at Clarinda has definitely demonstrated this fact. Erosion was compared on adjoining plots. On one the surface soil, which contained most of the organic matter, had been removed, while on the other the surface soil, containing a fairly large amount of organic matter, remained. From June 1, 1932, to Dec. 31, 1934, there were 70.35 inches of rainfall, and during that time 10.7 inches of water ran off the plot without surface soil and carried with it 102.9 tons per acre of soil, whereas only 8.7 inches of water ran off the plot with surface soil containing organic matter and carried with it 66.5 tons of soil per acre.

Although the entire beneficial effect of the surface soil in this case cannot be attributed to the organic matter in the soil, it is known that organic matter materially influences the physical properties of a soil, and it was undoubtedly responsible, in large measure at least, for the resistance the soil offered to erosion. Further experiments on the same soil have indicated that when corn is grown on the land the incorporation of organic matter in the form of green sweet clover or barnyard manure has reduced erosion to an average of approximately 20 percent of that of the check plot without organic matter. Similar applications of organic matter to fallow plots reduced erosion approximately 75 percent over plots without organic matter.

The application of organic matter in the form of barnyard manure has shown similar beneficial effects in the control of erosion on the Shelby silt loam at Bethany, Mo. The soil loss in 1933 from plots treated with organic matter was approximately one-fifth less than that which occurred on plots to which the manure was added.

Application of Phosphate and Other Fertilizers

The best growth of crops cannot be obtained on many of the soils of Iowa without the application of phosphates or other fertilizers. This is particularly true in the case of soils where erosion has occurred, and where a considerable portion of the more fertile surface soil has been washed away. On the badly eroded areas where maximum protection against erosion is needed, it is frequently difficult to get a good stand of the legume crops and even of the small grains and grasses. On these soils the application of a phosphate fertilizer aids materially in establishing the crop, and obviously the degree of protection against erosion afforded by the crop is directly related to the stand.

The application of such fertilizers aids in the control of erosion somewhat indirectly by increasing the yields per acre of corn and other inter-tilled crops. Thus greater amounts of organic matter are added to the soil in the crop residues. Furthermore, because of the increased yields of these crops on fertilized land, a smaller percentage of the total acreage is needed for their production in order to obtain the same or even higher income per farm. Hence, a larger percentage of the land may be used for growing grasses and legumes which are more effective than the inter-tilled crops in controlling erosion.

Phosphate fertilizers are rather generally needed on Iowa soils, and they have been found to give increased crop yields on practically all of the soils of Iowa that are subject to erosion. Either rock phosphate or superphosphate may be used with desirable effects on such soils.

In most tests complete fertilizers, or those containing nitrogen or potash, have not been found to give as economical increases in crop yields as those obtained by the use of a phosphate. On areas where most of the surface soil has been washed away, however, it is entirely possible that fertilizers containing either nitrogen or potash, or both, will yield profitable returns. No general recommendations can be made concerning the use of such materials, but it is suggested that they be tried on small areas of the farm before they are applied to large areas.

Fig. 27. Strip cropping is an effective means of preventing the loss of surface soil by erosion. The dense vegetative cover of certain crops holds the rainwater and prevents it from washing down the slope.

Fig. 28. A winter cover crop of rye or vetch aids greatly in controlling erosion on rolling land where inter-tilled crops are grown.

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Hordes of gullies now remind us
We should build our land to stay,
And, departing, leave behind us
Fields that have not washed away;
When our boys assume the mortgage
On the land that's had our toil,
They'll not have to ask the question,
"Here's the farm, but,
WHERE'S THE SOIL?"

—Tennessee Valley Authority.

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