

A SOIL SURVEY OF SEVENTEEN COUNTIES
OF SOUTHERN INDIANA.

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The Indiana Soil Survey.

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Indiana in area of square miles ranks but thirty-fifth among the States of the Union, but in its great natural resources it stands among the first; yet not including any of the precious metals its resources are varied in character and are very valuable, and the state is rapidly growing as a mineral producing and manufacturing center. The finding of natural gas and oil, the abundance of coal, the inexhaustible supply of limestone, good cement shales, excellent fire-clays, together with the splendid transportation facilities, have all added to the building up of great enterprises which have brought into the State millions of dollars to be invested in economic interests which are paying handsome dividends on the money spent. Yet among the most valuable of the natural resources of Indiana are the productive soils. All the great business enterprises are dependent to a large extent on the productiveness of the soil,

“For, nevertheless, whate’er befall,
The farmer he must feed them all.”

Indiana ranks high as an agricultural State, with her great crops of corn and wheat, her thousands of fine cattle, hogs and sheep, her blue grass pastures and meadow land and an increasing acreage of fruit. There are about 17,448,000 acres of tillable land in the State. The six chief agricultural products of the State are in the order of importance, corn, oats, wheat, timothy meadow, clover meadow and potatoes.

Many of the wealthy citizens of the State can today point back to the pioneer history of Indiana when their capital consisted of a few acres, a little log cabin, and an ax and some provisions and a large supply of persistent energy. Every one, as soon as possible, prepared a field for corn, started a garden, procured a few hogs, one or two horses, or a yoke of oxen and a few cows. It was rather easy in those days to keep live stock. The wild grass, nutritious roots, and several kinds of nuts and acorns were so abundant that neither horses, cattle nor hogs required much grain, and often large

numbers of farm animals were maintained. A surplus of corn, beef, pork, etc., was produced and low prices created a market, and profitable business began to grow. Demand led to a greater diversity of crops and an increase in commerce. The soil, though rich, requires and is well adapted to a great variety of crops. Thus step by step, year by year Indiana has grown to be a great agricultural State, with farms of the highest value, and her crop production and value of her live stock worth about \$250,000,000 in the year 1907.

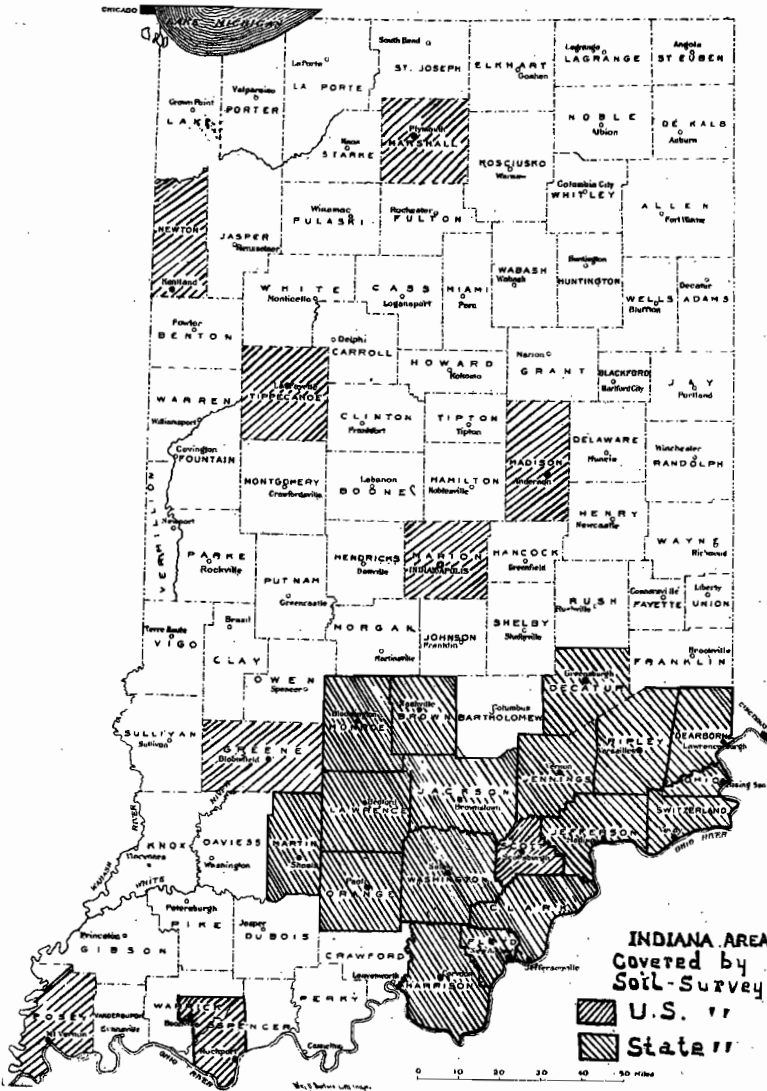
In view of the greatly increased price of land, the important question confronting the farmer is how to secure from his farm returns in proportion to the increased money value of the land. It is becoming more and more difficult to secure adequate farm labor, and thus the successful cultivation of large farms is becoming a problem. Future farming is to be intensive rather than extensive. The man who produces the same amount of grain on one-half the acreage does it at a great saving and at the end of the year will be much in advance of his neighbor who has expended the same energy in twice the acreage.

During past years farming in Indiana has been carried on with profit, but agriculture has not yet reached its highest possibilities with the great variety of soils of the State and the intelligence and industry of the farming population. Indiana soils have been made to produce 150 bushels of corn per acre, but now with the average production of corn per acre less than 40 bushels, something must be wrong under the present ordinary conditions of cultivation.

Many farmers are using some kind of commercial fertilizer as a means of restoring to the soil the elements needed, but too frequently the fertilizer has not been selected with any reference to soil conditions or composition, and the result would seem to show a further depletion of the soil rather than an improved condition. Many others sow clover to restore the native fertility to the soil, but fall short of their object by cutting off the first crop of clover for hay and the second crop for seed, and thus robbing the soil of the elements they wished to restore to it. The farmer who studies carefully the existing soil conditions and who uses care in selecting his fertilizers to restore deficient elements has done much to make agriculture an interesting and profitable occupation.

Soil Survey.—The future of our agriculture depends to a great degree upon a proper knowledge of the nature of our soils and how they can be best preserved and cultivated. While it is not necessary for the farmer to trouble himself with technical geology,

chemistry, botany, etc., it is one of the absolute requirements of successful, economic agriculture that he have an intelligent com-



prehension of the habits and demands of the plants he cultivates and a fair knowledge of the nature and requirements of the soil he tills.

Until within the past few years little attention has been given

to Indiana soils either by the geologist, scientific agriculturist or the farmer.

The State Department of Geology has made some investigation previous to the present survey, the Indiana Experiment Station has done a great deal in reference to a cropping system and the manurial requirements of certain types of soil. The Bureau of Soils of the United States Department of Agriculture has carried on some work on the soil survey in the past few years and has to the present time made a survey and published reports on ten counties, as follows: Marshall, Tippecanoe, Newton, Madison, Marion, Green, Scott, Posey and a part of Warrick and Spencer Counties. The State Department of Geology in 1907 made a survey of the following counties in Southern Indiana: Monroe, Brown, Lawrence, Jackson, Washington, Orange, Martin, Decatur, Jennings, Ripley, Dearborn, Ohio, Switzerland, Jefferson, Clark, Floyd and Harrison.

Maps were constructed showing the boundaries of the various soil types and numerous samples were collected and mechanical analysis made of these by the field men and a complete chemical analysis of typical samples were made by Dr. R. E. Lyons, Bloomington, Ind. His method of work and the results of the analysis are given under an included article written by himself. The analyses are repeated under the discussion of the various types from which analyses were made. These are compared also with other analyses that have been made and those of the residual soils are given in connection with analysis showing the average composition of the parent rock.

Throughout the survey the field men had the hearty co-operation of the farmers and by this many things of special interest and importance were developed that otherwise would have been unobserved. The following list of questions was sent out to farmers who might be interested in soil investigation and improvement; while many of the lists were never returned, many were returned, giving a full report of valuable information:

SOIL SURVEY OF COUNTY, INDIANA.

The State Department of Geology is beginning a Soil Survey of this County. The following is a list of questions relating to the soils. The conditions covering crop production are so complex that even with the fullest information, and the most careful work, cases are found in which as yet the best experts will be at fault. Your assistance in the work through the information to be gained from answers to the following questions will be greatly appreciated, and we trust the report may prove

beneficial to you. Your set of answers is important in compiling information in your neighborhood. If you can not answer all the questions, please answer those you can. The favor of a prompt reply, even though incomplete, will be highly appreciated.

QUESTIONS.

1. Name
2. Location of land.....Sec.....Twp.....Range.....
3. Color of soil
4. Character of soil
5. What crops are grown most successfully?.....
6. What is the average crop per acre of wheat?, of corn?
of oats?, of rye?, other grains of vegeta-
bles?
7. What fertilizer, if any, do you use?
8. What is the average sized farm in your part of the county?
9. Note any peculiarities of the soil and subsoil
10. Their behavior under tillage and cultivation of various crops
11. Their behavior in wet and dry seasons
12. Difference in the behavior of different portions of the same field or
soil area
13. Give any and every circumstance that can throw any light on the agri-
cultural qualities or peculiarities of the soil
14. Suggest any questions or suggestion for our consideration

Soil Maps.—It is impossible in some cases to obtain a base map of proper accuracy. In such cases it is necessary to use a plane table outfit and construct a traverse base map in the field. This traverse work can, however, be reduced to a minimum by making careful use of all data at hand and by continually checking up all minor errors which are encountered.

Most counties are provided with fairly accurate base maps showing township and section lines, towns, churches and schools. But often the roads and streams, especially the minor drainage, are much in error if shown at all.

In places where a topographical survey has been made, the mapping of the line between the upland and lowland is much facilitated. In parts where no topographic and but little geological work has been done, some plane table work is usually required where there is much valley or bottom land, with somewhat abrupt valley sides.

In a soil survey it is not necessary to attempt to construct a general topographic map, but areas rising to considerable distance above surrounding country, and distinct bluffs, or the occurrence of a hill in a generally level tract such as cut off hills and lost ridges, or terraces should be indicated by some special markings.

All mapping should be on a scale of not less than one inch to a mile and a two-inch scale is preferable, as the field mapping can be done more accurately and then the original may be reduced to any size for publication, but in no case should be smaller than one-half inch to the mile and if soil types are numerous and of small area, the printed map should be one inch to the mile. On a scale of one inch to the mile a square one-eighth of an inch on each side represents ten acres, and smaller areas can not be well represented, but if smaller areas are found of a distinct type they should be discussed in the notes. In many cases terraces can be mapped with the valley, but where of considerable area or of a distinct type should be so indicated.

If maps are to be published in colors the soil boundaries may be indicated by dotted lines and the area marked in with the color chosen for that special type. If to be printed in black and white as zinc etching, some system must be established for indicating the various types, which will make it distinct and so that when reduced will not appear too black, such a system may be made somewhat general but in some counties change will necessarily be made because of the diversified character of the soils. The boundaries may be indicated either by a solid or a broken line, and the boundary mark should be as light as possible to show distinctly, since a mark one-hundredth of an inch wide on the paper will represent a width of nearly fifty-three feet on the ground.

The Geological maps of the State which have been prepared and are being constructed at the present time, showing the outcrop of underlying rocks, the glacial and alluvial deposits of recent time, become the basis of a soil map or in a general way may serve as such a map. After such maps have been prepared it greatly facilitates all kinds of soil investigation.

In the case of hillsides or along slopes the formation outcropping high up in the hill influences to some extent the soils belonging properly to the lower formation. Otherwise a knowledge of the character and value of the soil derived from any given formation will apply to the residual soils of that formation whenever found. The geological and soil maps will show at once where such soils occur. It is then important that soil maps be made to correlate as far as possible with geological maps. Particular modification of the general type will occur and require mapping, and such mapping should be on a basis that will make the most profitable and intelligent application to the farmer of that area. While the line between the soils of different formations and soil types can-

not be defined to a space of a few feet and the same general farming principles may seem to apply, the soils upon investigation may be entirely different and require a different treatment and are adapted to special crops in order to secure the best results.

AGRICULTURE.

History of Agriculture.—Agriculture as a science is based upon a group of sciences which in their growth have revolutionized it. The most important of these are chemistry, botany, zoology and geology. There are many divisions of agriculture referred to under various terms, as tillage, husbandry, grazing, dairying, feeding, breeding, horticulture and arboriculture, and care of all vegetables and animal life supported by the earth for the benefit of mankind.

Agriculture is one of the oldest of human employments, dating from long before the dawn of history. The inhabitants of the lake dwellings of Switzerland were perhaps the earliest tillers of the soil and stock keepers about whom we know. Among their dwellings we find the bones of cows, pigs, sheep and goats as well as of wild animals. Grain crushers were in every dwelling. Wheat, barley, millet and flax seem to have been cultivated. The Aryan peoples are believed to derive their name from a word which indicated that they were users of the plow, and were thus distinguished from other people. Most of our knowledge of the earliest agriculture clusters about the river valleys—that of the Nile in Egypt, and that of the Tigris and Euphrates. In Oriental agriculture the great need is water. In Egypt once a year the Nile comes to the relief of man, gives him the water for a crop and prepares the bed for the seed. Sir Isaac Newton claimed that agriculture began in the Nile Valley, and that the river taught men the art. Its teeming population that anciently existed in that narrow valley, the large army maintained, and the great engineering and architectural works constructed indicate a successful cultivation of the soil. Seeds were sometimes sown upon the mud and trodden in and when the soil needed stirring a pick was used constructed of two sticks tied together. Then came the rude plow formed by fastening together a pointed share, two handles and a pole. Sowing was always broadcast and the heads of grain were cut from the stalks and carried to the threshing floor.

Of Babylonian agriculture there are few records, but as in Egypt, a dense population was supported. The Euphrates over-

flowed but did not do the work of the Nile. In all the region irrigation turns desert lands into fruitful fields.

The Scriptures are full of allusions to the operations of husbandmen in Palestine as well as in Egypt. The laws were those of an agricultural people. Extensive plains of fertile soil yielded the finest wheat. The hillsides were covered with vines and olives often planted in terraces formed with much labor to afford a large mass of soil in which the plants might flourish in the dry season. The valleys were well watered and afforded pasture for numerous flocks. Little is known of early Grecian agriculture. It has been said they knew the value of the scarecrows and when these failed had a sure charm produced by carrying a toad about the field by night, and then burying him in the middle of it. They used a plow similar to the Egyptians, and plowed their ground several times. Manures were used and soils were combined for fertilizing purposes.

Roman agriculture has received special attention since so much was written about it by the Romans themselves, and since they carried it into other countries where it modified or dominated agricultural customs when Rome was only a colony on the Tiber, land was divided among the citizens in small allotments. The common conditions were that the occupants paid one-tenth of the produce of the corn lands, one-fifth of the product of the vines and fruit trees and a moderate rate per head for cattle pastured. Later the place of the small farmer was taken by the planter, who cultivated a large territory with slave labor. The chief grain cultivated by the Romans was wheat, with barley second, and meadows were also highly valued. They believed in and understood crop rotation. After the overthrow of the Roman Empire the conquering people began to study the works of Roman agriculture and all western Europe agriculture was benefited. In England at the same period the agriculture showed alterations of indolence and bustle. In August, 1317, wheat was twelve times as high as in the following September. Rye was the breadstuff of the peasantry. Little manure was used and the soils became less productive.

The discovery of the New World showed two grades of agriculture carried on by those who had even used a plow similar to the Egyptians, and plowed their ground several times. Manures were used and soils were combined. The great contribution of America to the world's agriculture was the three plants, the potato, tobacco and Indian corn or maize. In the region north of Mexico the labor of planting and caring for the scanty crops was performed by the

women, who broke the ground with the rudest possible implements. The leading agricultural writer of the sixteenth century was Sir Anthony Fitzherbert, who published his "Book of Husbandry" in 1523. In this century agriculture became more profitable. Gardening greatly neglected in the first part of the 17th century, received much attention in the latter part. Deep drainage was much talked about and crop rotation was carried on successfully. And thus the beginning of the 18th century saw a great revolution in English farming.

English agriculture of the first part of the nineteenth century was marked by the influence of Arthur Young, who traveled much, carefully observed, experimented somewhat, and wrote industriously. He was one of the first to make experiments in regard to nitrogen and in regard to ammonia, previously supposed to be injurious to vegetation. Of his works one has recently been republished. As secretary of the Board of Agriculture, established in 1793, he was concerned in the discussion of all the agricultural questions of the period. Jethro Tull, whose book on Horse-hoeing Husbandry appeared in 1731, was almost in touch with the methods of the nineteenth century. His theory was that seeds should be sown in drills and the spaces between the drills kept thoroughly cultivated. He asserted that the plant lives upon minute particles of soil and obtains food from the air when the soil is brought to dust. He invented a drill and a horse-hoe. He did not succeed in obtaining a large crop; but modifications of the method have since been made. Considering that Tull did not have the aid of agricultural chemistry, he could not more nearly have touched hands with the scientific observers of today. In one respect there is an approach to his position. The supposed proof that plants cannot take nitrogen from the air has been questioned since 1880. At present it is generally accepted that certain (if not all) plants do require the plant food nitrogen from the air. The theories of Tull may acquire fresh interest through the present discussion of the relations of the physical properties of the soil to the cultivation of plants.

The white colonists of North America had much to discourage them as agriculturists, and in New England the additional drawbacks of long winters and a rocky soil. The colonists in Virginia found both Indian corn and tobacco, the latter fitted to become an article of export. The New England settlers brought with them English modes of farming. From the Indians they learned how to raise corn, breaking the soil with a hoe and manuring with fish. Corn was the great product to be depended upon, although other

grains were cultivated and cattle and sheep increased slowly, fed first upon the native grass, then upon the herd grass specially fitted for New England soil.

Potatoes began to be raised in the first part of the eighteenth century. The Southern colonists, more favored by nature, made less actual progress than those of the North. An important part of the little written upon agriculture was the volume of essays published by Jared Eliot, 1735. Even as late as 1790, as we learn from McMaster's History of the American People, little progress was made. Throughout the South it was the common practice to grow crops without rotation, and in general manure was thrown away.

Marked changes have taken place in the agriculture of the past fifty years, in a great part due to the development of agricultural chemistry. Among the results of the study of agricultural chemistry have been an extensive use of chemical fertilizers, selected with reference to soils and crops and a comparative independence of the fixed rotations. Researches, however, are not confined to agricultural chemistry. The work as carried on in more than three hundred experiment stations of the world is planned to attack one after another the pests and the problems that confront the farmer. Other features of the great progress are, the extensive introduction of machinery, careful cultivation, thorough drainage and deep plowing. Market gardening or "truck farming" has been made a branch of agriculture.

Agricultural Education.—It is only within recent years that adequate attention has been paid to agricultural education. The first agricultural school was founded by Fellenberg, at Hofwyl, in Switzerland, in 1806. His pupils were taken from the poorest class of peasantry, of whom he truly observed, that "having no other property than their physical and mental faculties they should be taught how to use this capital to the best advantage," by a combination of "discipline, study and manual labor." No fewer than 3,000 pupils were trained in this school, which flourished for about thirty years. Since then various schools of like character have sprung up in Europe. The French Government makes large appropriations to support agricultural education and one school at Grignon has an old royal palace with its domain of 1,185 acres. In Prussia there is scarcely a province that does not boast of its agricultural school and model farm; and throughout Germany, as well as in Russia, we find educational institutions supported by the state, in all of which agriculture is practically as well as theoretic-

cally taught. Finland possesses in all ten agricultural schools and seventeen small dairy schools. Denmark spends about \$55,000 annually. Japan has an agricultural college on the island of Yeso, and an experimental farm in the province of Shimosa, near Tokio. In Great Britain a large number of colleges and secondary schools teach agriculture, and in some of the best schools a full course of agricultural education is given, as at the Royal Agricultural College and the College of Agriculture, near Salisbury. At the University of Edinburgh, practical agriculture is acquired by residence on a farm near Edinburgh, and by Saturday excursions to selected farms near at hand. The most important experimental station in England is a private one at Rothamsted. Woburn Station is next in importance and was started in 1876 by the Royal Agricultural Society.

In 1847 the United States made the first step toward agricultural education, when John P. Norton, agricultural chemist, just returned from Europe, agitated the question of agricultural schools and one school was begun. In 1860 it was liberally endowed by Joseph E. Sheffield and is now attached to Yale College as the "Sheffield Scientific School." In 1852 a similar school was started at Dartmouth College.

Congress was repeatedly asked to set apart lands for the support of agricultural colleges, and a bill was passed in 1858 for that purpose, but the president failed to sign it. In 1862 the effort was successful, and a bill became a law appropriating about ten million of acres to all the states, to be divided according to the number of representatives from each state in Congress. Meantime, New York and other states kept the question alive and Michigan opened her Agricultural College in 1857; and now, under one or another name, nearly all the states have colleges or parts of colleges in which agriculture is taught.

The Department of Agriculture was established in 1862, though the first distribution of seeds, etc., was made by the commissioner of patents in 1836. The first garden was established in 1858. The object of the department is to acquire and disseminate among the people of the United States the latest and best information on the subject, and to introduce into the country new and desirable seeds, plants, etc. The divisions of the department are seeds, propagating garden, pomology, ornithology, forestry, and library, chemistry and the Weather Bureau. Monthly reports on the state of crops and kindred subjects are issued and farmers' bulletins are printed and distributed throughout the country. Year books are

also published, giving the progress of the work of the department for the past year, and includes many valuable papers upon subjects relating to the various divisions of agriculture.

Agricultural Experiment Stations are now in operation in every state and territory and are carrying on a large amount of scientific and practical work, giving results of great value to American agriculture. These stations are departments of the agricultural colleges and were first established under act of Congress of 1887, and intended "to promote scientific investigations and experiments respecting the principles and applications of agricultural science." They conduct researches with regard to the physiology of plants and animals, the advantages of rotative cropping, the analysis of soils and waters, and the chemistry of manures, foods, etc. The act of 1887 appropriates \$15,000 annually for each state for the purposes of such stations. The officers of the stations report to the Department of Agriculture, and publish bulletins giving results of experiments. They enjoy now more than ever the support of farmers, horticulturists, etc. A number of the states have liberally supplemented the funds appropriated by Congress for the maintenance of the stations. So great has been the success of the stations, and so urgent have been the demands for the information which they are able to give, the calls for the preparation of popular bulletins and the delivery of addresses at farmers' meetings, that it has in some cases been almost impossible to meet the demand without endangering the success of the original investigations which it was their first business to conduct. While the farmers of the country may well congratulate themselves on having such numerous and important agencies for the discovery of new truths and the dissemination of useful information, they should not relax their efforts to aid the stations in advancing their work and securing the greatest benefits to agriculture which can be obtained with the resources at their command. Fitness and ability to carry on successful investigations should be the fundamental qualifications for station officers, and when competent men are once obtained they should be held in their positions and supported in their efforts to plan and carry out thorough experiments.

Agricultural societies for the purpose of promoting the interests of agriculture have sprung up in great number, farmers' congresses, farmers' institutes, boards of agriculture, state and county fairs, horticultural societies, experiment clubs, are all means of education for the farmer. In Oklahoma farmers are forming "acre clubs," each member taking one acre for an experimental crop, doing his

best with it, and when the season is over, reporting his experience, including mistakes, and describing his methods. This is a practical form of agricultural education and the plan might well be tried in other places.

In the secondary schools of our rural communities agricultural instruction is growing in importance. The effort to introduce nature study largely on subjects relating to agriculture is being actively undertaken in several states. The result of pushing this educational motive into the rural communities has caused a most decided waking up of those communities. For many years schemes for the teaching of agriculture in the common schools have from time to time been put forward and have attracted more or less public attention, but none of these have been found practicable. This is largely because they have ignored the conditions existing in our common schools, as well as the nature of the subjects with which the theory and practice of agriculture deal. The art of agriculture is best learned on the farm. That is the place where the boy learns how to plow, plant and reap, and how to feed and care for stock. It is true that at an agricultural college or other school where the farmer boy may reside for a considerable time, he may learn new and better ways of doing these things than on his father's farm, but the chances are against him in the rural school, since most of the time must be taken up with the rudiments of a general education. In his school he must be taught the principles underlying agriculture; that is, he must be taught why he plants and plows and reaps in one way rather than another, and what laws of nature he violates in his bad management that his crops do not yield and his stock do not grow and fatten. This education must also be carried into the high school, where large numbers of farmer boys and girls complete their education. These schools are located near their homes and they are unable to attend the longer and more expensive college courses. Any school so far distant from the farmer's home as to require the boys and girls to be away from home two years or more is too expensive for most of the farmers' children after they have reached the age when they will be of service on the farm. What then is needed is courses in agriculture in the common schools and in numerous high schools to which farmers' children resort, near their homes, to "finish" their education after they have completed the common schools. The more practice the boy has had on the farm the better able he will be to appreciate a systematic course in agriculture. Such instruction in the secondary schools will open the mind of the pupils to the wonderful progress

which is being made in agricultural science and practice. It will enable him to take a more thorough advantage of the information furnished through books, bulletins of experiment stations, farmers' institutes, home reading clubs, etc. The farmer must be taught to think in the lines where science has shed light upon his art if his practice is to be most thoroughly successful. Fortunately, science has already much to tell the farmer which is most useful to him, and every year sees an increase from which the agricultural student can safely draw.

SOILS IN GENERAL.

Soil.—Soil is the loose mantle of material covering the surface of the earth. It consists of the disintegrated materials of the earth's crust mixed with varying amounts of decayed vegetable matter. The earth's crust is composed of more than seventy elements, most of which are present in very small proportions. Of the numerous elements known, only eighteen are of importance either in soil formation or plant growth, and of this list, three or four have no active part in normal plant growth. They are as follows: Metallic elements—potassium, sodium, calcium, magnesium, iron, manganese, aluminum, and titanium; non-metallic elements—carbon, hydrogen, oxygen, nitrogen, phosphorus, sulphur, chlorine, fluorine, iodine and silicon. Iodine and titanium perform no important function in soils and plant growth. The value of fluorine is little known, but it is found as an ingredient of animal bones and its presence is often found in plant ashes. Aluminum in the form of its compounds with oxygen and silicon is a very prominent soil ingredient and has an important place in the physical properties of the soil, but does not perform any direct function in plant nutrition, and is absent in the ash except in a few low forms. The remaining fourteen are always present in plants, carbon, hydrogen, oxygen and nitrogen forming the volatile part, while the rest occur in the ashes. Thus these various elements supply singly, or in combination, all the constituents necessary to plant growth, each of them having its own portion of the plant to sustain—the silica producing strength and rigidity to the stem; aluminum giving tenacity to the soil, and thus rendering it a stable support; magnesia perfecting the seeds; iron absorbing oxygen and ammonia from the atmosphere, and giving it up as required, and so on. Of these ingredients, silica, aluminum, lime, along with the organic matter, constitute the bulk of the soil, the others existing only in small quantity, and hence is derived

the common division of soils—siliceous or sandy, argillaceous or clayey, calcareous and humus.

The relative abundance of the elements found in the crust of the earth shows that one-half of the total consists of oxygen, and thus we find that most of the other elements exist in combination with it as "oxids." The oxid of silicon predominates over all other substances, while quartz occurs alone in large masses, the greater proportion is found in combination with other oxids—those of aluminum, calcium, iron magnesium and the alkali metals, potassium and sodium.

Subsoil.—Immediately beneath the soil or stratum of earth which affords nourishment to plants, is a mass of earth or rock, unmixed with decayed matter, to which the term subsoil is applied. The subsoil may or may not be similar in its geological constitution to the soil. The term "surface soil" is generally applied to that part of the soil turned over in cultivation, and the subsoil is all that part of the soil mass extending down from the surface soil. This is a distinction of practical importance, but the real distinction is due to the action of organic matter and certain physical and chemical causes. In the latter case the surface soil may be only a few inches in depth, or may extend downward several feet. The subsoil is usually of lighter color, due to the absence of organic matter, except where there is deep coloration caused by the presence of iron. Another striking difference between soil and subsoil is the degree of compactness of the material in two layers and also the extent to which the earth is mixed with fragments of the parent rock. The agencies acting upon the surface tending to give it a loose, open structure, do not act in the subsoil, and it therefore remains in a more solid form.

Soil Formation—Rock Weathering.—Rocks are simple mineral aggregates; and a few only, limestone, quartzite, etc., expand or contract alike throughout; with each change of temperature there is a tendency to form fissures, which will gradually lead to the disruption of the rock surface. Temperature changes, therefore, is an important agency in the breaking down of rocks. Disintegration is effected partly by the chemical action of oxygen, carbonic acid and the other acid or alkaline substances brought by the atmosphere to bear upon rocks and partly by the wearing action of water in a fluid state or in the form of glaciers, or by its expending force when broken. Almost any locality will afford opportunities for observing the nature of the process by which soils are made. We may examine the exposed rock of some old quarry where the

soil covering has been removed and the rock is again left to recover its coat of loose material. Even where quarries do not exist, an old pavement will often show the soil-making process. Water and the atmosphere and the heat of the sun coming upon the earth's surface are the important agencies by which the rocks are pulverized. The drops of rain water as they fall upon the rock surfaces tend to loosen small particles from the partly decayed rock. The water soaks into the minute fissures of the rock and dissolves the cementing material so that the grains of sand, mud, etc., are more easily broken loose by the blows of other rain drops. In freezing, the water that has been absorbed by the rock surface expands, and masses of rocks are broken into fragments by the agency. Cracks and crevices are made larger and a large amount of new surface is exposed, and the smaller particles are torn loose and added to the mass of accumulating soil.

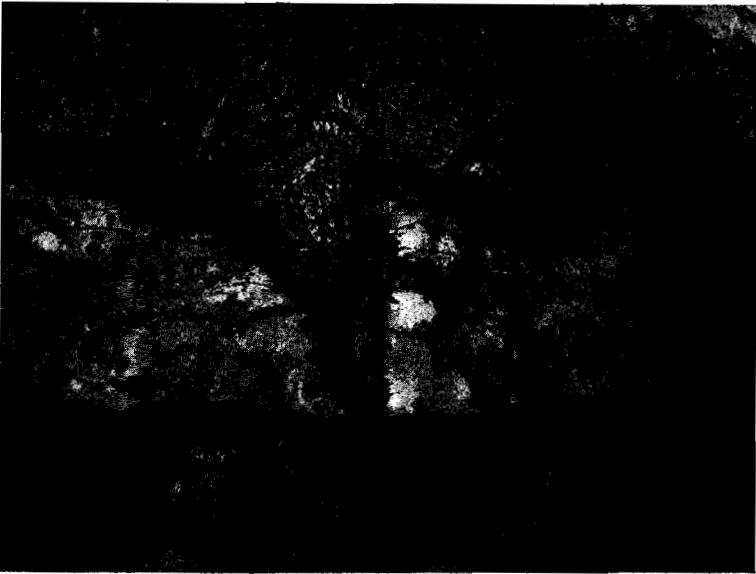
After the rock surface begins to decay, low forms of plants become attached and absorb certain portions of mineral matter by the broad adhesions which bind them to the surface. As soon as the surface has secured a coating of these lichens the process of soil-making goes on with increased rapidity. These plants are active only when they can obtain sufficient water from the moisture of the air and the surface on which they rest. The decay of the lichens supplies the water with a certain amount of carbonic acid gas, by which the solvent power of the water is increased in its effect of disintegrating the rock.

“Among siliceous rocks, chemical action proceeds but slowly, and the amount of material actually removed in solution is rarely over 60%, and may be so small that the residue in extreme cases occupies some 80% more space than the rock from whence it was derived. Carbonate of lime, the essential constituent of ordinary limestone, is, however, as has been observed, soluble, in the carbonated water of rainfalls, and in time, may undergo complete removal, leaving but the insoluble impurities behind. This is, indeed, the universal history of limestone soils. They are, however, infrequently so siliceous or ferruginous as to be quite barren and of a nature to be benefited by the application of lime as a manure.

“Throughout the areas occupied by the Trenton limestones, in Maryland, nearly every farm has, in past years, had its quarry and limekiln where the stone was fitted for supplying lime once more to soils from which it had been so thoroughly leached as to render them lean and poor. It is to this solvent action that is due the formation of the multitudinous caverns, large and small, of the lime-



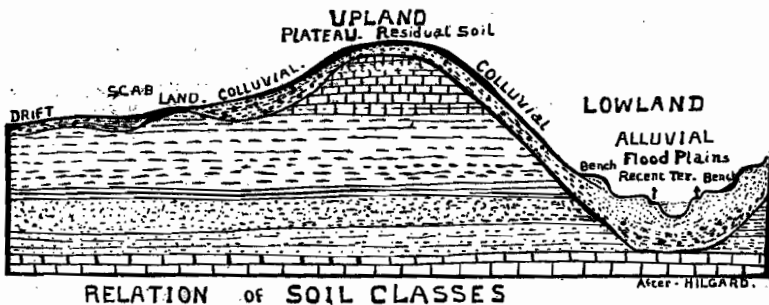
Illustrating manner in which the roots of trees break up rock masses in the Harrodsburg limestone, one and a half miles north of Bloomington, Monroe County, Ind.



Illustrating same as above; also shows low forms of plant life attacking the surface. Notice the large root after passing through the crevice again widen out. Near Oliver Quarry, southwest of Bloomington.

stone regions. Even where caverns are not present, the corrosive action is evident to the practised eye. In the quarry regions of Tennessee surface blocks of limestone are often grooved to a depth of an inch or more with the acids absorbed from the atmosphere and surface soils, while in the quarry bed the stone is found no longer in continuous layers, but in disconnected boulder-like masses. In such cases casual examinations give very little clew to the rapidity of the destruction going steadily on, since all is removed in solution excepting the comparatively small amount of insoluble matter (usually clay or silica) existing as an impurity."*

Classification of Soils.—The determination of the true relationship of the soils of different areas is a difficult problem, since, being derived from rocks of all kinds and under varying conditions, no fixed lines for soil classification can be laid down. But for the purposes of discussion and definition we have the primary divisions of sedentary and transported soils, and each of these is again subdivided according to the agencies involved in its transportation or original formation.



1. *Sedentary or Residual Soils*—(a) *Residuary*, (b) *Cumulose*.—These are known as soils in place and have not been removed from the parent rock. The rock underlies the soil or subsoil at a greater or less depth, and the soil bears some characteristics of the original rock. The upper part of the rock surface is generally somewhat broken and decayed, with fragments scattered through the subsoil. The prevailing characteristic of an old residual deposit, from whatever rock it may be derived, is a ferruginous clay. With the exception of quartz, the various mineral constituents are often in advanced stage of decay, and the more soluble constituents are wholly or partially lacking, having been leached out. In the case of limestone the soils consist mainly of aluminum and fer-

*Geo. P. Merrill, "Rocks, Rock Weathering and Soils," pp. 245-46.

ruginous matter, grains of sand, and nodular masses of chert which existed as admixed impurities. At first one would believe the residual soils derived from limestone to differ greatly from soils originated from sandstones or shales, yet the difference is not so great. There usually overlies the sandstone strata a loamy earth, not very different in character from that overlying the limestone. It is somewhat more sandy, and thus less cohesive, and becomes less so farther from the surface, while in the limestone region the toughest clay lies next to the surface rock. The limestone clay shows a tendency to cleave, breaking up into little pieces which are roughly cubical. The residual soils occur principally on plateaus and gentle slopes, where the velocity of the surface water from rainfall is not sufficient to dislodge the rock debris.

Another group of soils to be classed as sedentary are in cumulative deposits, as peat, muck and swamp, since they result from the gradual accumulation of material "in situ" through differing in both composition and origin from those just described.

2. *Transported*.—Because of the transporting power of water, wind and ice, few residual materials are left undisturbed for any length of time but become more or less intermixed with materials from near or distant sources. It is through the influence of running streams, both in the past and present, and moving ice in times past that has been brought about the great mass of material known as drift. According to the agencies involved, we have a variety of transported materials.

(a) *Colluvial Soils*.—These colluvial soils form a large part of rolling and hilly uplands, and are of varying degrees of productivity. They owe their origin to soils removed from the original site to such a degree as to become intermingled with the soils of other rocks, or by the rolling or sliding down the slopes the particles become more finely divided, and the soil masses are subject to landslides from penetrating waters underneath and from complete saturation and from hard freezing and rapid thawing, but ordinarily the movement down the slopes is slow, yet perceptible in a short time. Sedentary soils are dependent almost entirely on the parent rock for their specific character, and nearly the same is true in the case of colluvial soils.

(b) *Alluvial Soils*.—The alluvial soils are those of the valleys, flood plains, sea and lake borders. The materials of which these soils are composed have been gathered from all along the course of the stream and may consist of a great variety of components. and although they may vary greatly in their character, they are

usually fertile. They are usually of fine texture, but the relative proportion of sand and clay are dependent upon the velocity of the water current. In the upper part of the valleys and where the slope is relatively steep and the velocity great, there is a large proportion of coarse stones and gravel, and as the slope and velocity decrease, coarse and then fine sand will be the prominent component of the soil, while farther down the stream the finest sand, silt and clay are the principal constituents. The alluvial soils differ from those thus far described in that they are always more or less stratified.

(c) *Aeolian Soils*.—These deposits owe their origin and present structural features mainly to wind action, but sharp lines cannot always be drawn between them and those of alluvial types. The principal occurrence of such soils are in the Loess deposits and in the sand hills or dunes, and to a small degree the volcanic dusts.

(d) *Glacial or Drift Soils*.—Ice in the form of glaciers has great eroding and transporting powers. The moving of the ice, with its embedded stones, cuts, scores and grinds even the hardest rocks, and the product is largely very fine and easily transported by the glacial streams. The fineness of this material renders it very suitable for the making of soil, and such soils are usually very productive and lasting. The rotten and mechanically mixed detritus of many rocks from many sources forms a soil which is abundant in all the necessary plant foods, and hence does not require a large outlay for commercial fertilizer as do other soils.

The material of the glacial drift is spread out over the land in a manner far from uniform and under varying conditions, and may be separated into two classes: (a) stratified or assorted drift, laid down under the influence of water, (b) unstratified or unassorted, deposited directly from the ice and consisting of a heterogeneous mass of coarse and fine material. A large part of the drift is composed of this unassorted material, consisting of clay, sand, gravel and boulders, to which the name till or boulder clay is applied, or, from its mode of deposition, the ground moraine. The accumulation of rocks and debris of all sizes in the moraines form glacial-made lands which cover extensive and important agricultural areas; such areas are undulating and the soil usually has imbedded in it stones of great variety and size.

Varietal Names.—In a general way, "rock powder," "clay" and "humus" are the chief constituents of soil. According to the predominance of one of these over the others, soils are classed as

“heavy” or “light.” Clay soils are usually heavy, while sandy and humus soils are spoken of as light. As regards the degree of fineness of the rock particles, together with the physical and chemical properties, soils are known as gravelly, sandy, silty, loamy, calcareous, siliceous, magnesian, ferruginous and others of local importance.

Soils of sedentary origin are usually spoken of in regard to the rock from which they were derived, as granite soil, limestone soil, etc. Transported soils are designated by the names given in above description with such local variations as indicate their production and adaptability. A loam is usually defined as an admixture of sand and clay with more or less organic matter, a clayey loam being one in which clay predominates and a sandy loam one which has sand prevailing. Peat and muck are known as humus soil. Silt, loess and adobe are terms applied to fine soils of varying origin. Swamp, marsh and meadow designate low-lying, wet tracts. In addition to these, many local names are used which in general have no special significance.

Soil samples are separated by mechanical means into various sizes, and the various percentage relationships determine the soil type, as coarse, medium or fine sand, sandy loam, silt loam, clay and clay loam.

It has been found through soil investigation in the United States that a given set of soils are so evidently related through source of material, method of formation, topographic position and coloration that the different types constitute merely a gradation in the texture of an otherwise uniform material. Soils of different classes thus related constitute a series. A complete series of soils consists of material similar in many other characteristics, but grading in texture from stone and gravel on the one hand through the sands and loams to a heavy clay on the other. Soils may, however, be very similar in origin and texture but may occupy so entirely different topographic position that their relation to crops is entirely changed and the use of another serial name should be applied.

Soil Coloration.—Another division of soils is that on the basis of natural colorations. Farmers use soil colors as a basis in determining the quality of land.

A black soil is considered a rich soil. The black or brown-black color is with few exceptions due to the presence of much humus. The shade of the black deserves close consideration. If tending toward brown, acid humus or “sour” land is indicated. The jet

black tint is an indication of calcareous land, and these are almost always highly productive.

Red soils take second place except in such cases where the red soil has been derived from ferruginous sandstones, that furnish little else but quartz and ferric hydrate. It is not the iron content that renders the land productive, but its presence is a sign of other favorable conditions: that a red soil is a well-drained soil, that ferric hydrate absorbs moisture and gasses, and, like humus, it renders heavy clay soils more easily tillable.

Yellow lands owe their color to smaller amounts of ferric hydrate, and share somewhat in the advantages of the red.

White soils or those of very light color are not usually considered of much value. The light color means the absence of both humus and ferric hydrate, and usually implies that the soil has been subject to reductive maceration through the influence of stagnant water; the ferric hydrate having been reduced to ferrous salts, the humus oxidized away, and most or all of the lime, iron and phosphoric acid of the soil mass accumulated in the form of inert concretions. The term "craw-fishy" is commonly applied to such soils, since they are usually inhabited by cray-fish, whose holes reach water a few feet below ground, and are surrounded on the outside by piles of white subsoil mixed with black gravel or concretions of bog iron ore. Such lands require careful drainage, and even then produce poorly, and are in immediate need of fertilization by green manuring and the use of phosphates.

Chemical Elements Important to Agriculture.—As stated above, eighteen elements require mention in connection with either soil formation or plant growth. The most important of these will here be discussed more fully in reference to plant growth and the use of natural and artificial plant foods.

Potash, phosphoric acid and nitrogen are three substances needed by all plants and crops for their food. These are taken up from the soil by the roots of plants and are contained in the crop which is harvested and removed from the farm. Hence, by continued cropping a soil becomes depleted of its plant foods, or "worn out" and unproductive. These three plant foods can be given back to the soil either in the form of natural or artificial manures, all of which contain one or more of these plant foods. Potash, phosphoric acid and nitrogen are equally important as plant food and one cannot take the place of another. Potash is necessary for the formation of starch, sugar and woody fiber in plants. Phosphoric acid is needed for the formation of seed, and

nitrogen is necessary for the production of leaves and stalks. But when nitrogen is in excess it will cause a rapid and excessive but watery and unnatural growth of wood at the expense of fruitfulness.

Until within the last century, stable manure, composts, etc., were practically the only fertilizers known and used, and the use of these might have continued indefinitely but for the attention of chemists, such as Liebig, who discovered the use of mineral fertilizers.

“The chemical composition of stable manure does not, alone, suffice to explain its efficacy and the difficulty of replacing it by any other material. The composition of manure, of course, differs not only with different animals but also with the different feeds consumed by them; but the average composition of farmyard manure is approximately given thus by Wolff and others:

ANALYSES OF VARIOUS FARMYARD MANURES

	1.	2.	3.	4.	5.
Water.....	71.00	75.00	79.00	79.95	72.33
Dry matter.....	29.00	25.00	21.00	20.05	27.67
Ash ingredients.....	4.40	5.80	6.50		5.87
Potash.....	0.52	0.63	0.50	*0.84	0.69
Lime.....	0.57	0.70	0.88		0.85
Magnesia.....	0.14	0.18	0.18		0.14
Phosphoric acid.....	0.21	0.26	0.30	0.40	0.30
Ammonia.....					0.02
Total nitrogen.....	0.45	0.50	0.58	0.78	0.46

1. Average composition of fresh farm manure (Wolff).

2. Average composition of moderately rotted farm manure (Wolff).

3. Average composition of very thoroughly rotted farm manure (Wolff).

4. Mixed cow and horse manure from a bed two feet thick, accumulated during the winter in a large covered yard, and packed solid by the tramping of cattle (the analysis by F. E. Furry).

5. "Box manure," consisting of mixed manure of bullocks, horses and pigs (Way, Royal Agric. Soc. Journ. 1850, II., 769).

*And Soda.

“It is thus seen that the percentage of the important plant foods in stable manure are minute when compared with those commonly found in “commercial” fertilizers. Nor are they so much more available for plant absorption than the latter; a very large proportion is not utilized at all the first year, and unless the amount applied is very large it hardly carries the supply needed for the usual crops.

“It is now well understood that its efficacy is largely due to the important physical effects it produces in the soil. It helps directly to render heavy clay soils more loose and readily tillable. If well “rotted” or cured it also serves to render sandy, leachy soils more retentive of moisture, and the humus formed in its pro-

gressive decay imparts to all soils the highly important qualities discussed later. More than this, the later researches have shown that stable manure acts perhaps most immediately upon bacterial activity in the soil, greatly increasing it not only directly by the vast numbers of these organisms it brings with it but also in supplying appropriate food for those normally existing in the soil. In so doing it serves to render the soil ingredients more available and to impart to the soil the loose condition required in a good seed bed—a “tilth” which cannot be brought about by the operations of tillage alone.

“The only possible substitute for the use of stable manure is found in green-manuring with leguminous crops conjointly with the use of commercial or mineral fertilizers. Unless this is done, the use of the latter alone ultimately leads to a depletion of humus substances, which render the acquisition of proper tilth by seed-bed impossible, and causes a compacting of the surface soil which no tillage can remedy.”*

All stable manures contain potash, phosphoric acid and nitrogen, but nearly always too much nitrogen in proportion to the mineral fertilizers, that is, potash and phosphoric acid. Therefore, when using stable manure, it is best always to add potash and phosphoric acid to it, so that the manure may have its full effect. It is not necessary to apply plant food in the form of stable manure. Potash, phosphoric acid and nitrogen can be bought and used in the form of commercial fertilizers usually at a less expense than in the form of a manure.

The principal sources of potash are the potash salts from Germany, and the most important of the potash salts are sulphate of potash and muriate of potash and kainit; the former two contain about 50 per cent pure potash, and kainit contains about 12½ per cent. Sulphate of potash is best for tobacco and some other specialties, while muriate of potash is somewhat cheaper and is useful for most crops. Kainit, in addition to its effect as a potash fertilizer, is useful for killing grub worms and other insects living in the soil, and is a remedy against cotton blight. Wood ashes are also a source of potash, containing from 2 to 7 per cent pure potash. Their composition is varied and uncertain.

The main sources of phosphoric acid are the large deposits of phosphate rock in South Carolina, Florida and Tennessee. The phosphoric acid in these rocks is insoluble and must be made soluble by chemical treatment before it can be used to advantage.

*Soils, E. W. Hilgard, pp. 73-74.

The phosphoric acid in the rock becomes then "available." Other sources of phosphoric acid are bone-meal, bone-black and thomas slag.

The most important nitrogen fertilizers are nitrate of soda, sulphate of ammonia, cottonseed meal and animal refuse, such as dried blood, dried fish, etc.

For the permanent improvement of soils it should not be overlooked that lime and organic matter (humus) are also frequently needed. Lime is especially useful on sour soils and makes them sweet. Humus is the product of decaying plants and is useful to make soils more loose and retentive of water. It may be furnished either by using stable manures or by green-manuring, especially with leguminous crops, such as peas or clovers. In the case of green-manuring, humus is produced directly through the decay of plants plowed into the soil, and in the case of stable manure indirectly after the plants have passed through the digestive organs of the animals.

Fertilizers or fertilizing materials, that is, chemicals containing potash, phosphoric acid and nitrogen, are applied either broadcast or in the hill or with the drill. Each method has its preference in certain cases. Broadcasting of fertilizers is best where intensive culture is practised and large quantities of fertilizers are used. Applying in the hill or with the drill has been found more effective in case only moderate quantities of fertilizers are given. Top dressing is practised usually only in case of fertilizers containing nitrogen, such as nitrate of soda, because these nitrogen materials quickly wash into the soils through the rains.

When unmixed fertilizing materials are used it is best to apply the mineral fertilizers, that is, those containing potash and phosphoric acid, some time previous to planting, in which case there will be sufficient time for them to disseminate in the soil and get well mixed. The materials containing nitrogen are then used at the time of planting or immediately afterwards as top dressing. When mixed fertilizers are used, it is usually best to apply immediately before planting.

The quantities of fertilizers to be used per acre are dependent on the soil and the crop to be grown. Usually to a soil which is in good condition larger quantities of fertilizers can be given to advantage than to a soil which is in poor physical condition, that is, either too hard, void of organic matter or poorly drained. The amounts of complete fertilizer applied usually vary from about 400 pounds to 3 tons per acre.

Plants differ in their requirements of the three essential plant foods. For example, all plants producing sugar and much starchy matter, such as potatoes and fruit crops, need much potash, while leguminous crops, which have the power of absorbing nitrogen from the air, can get along with a small supply of nitrogen in the soil. Fertilizers, therefore, must differ in the proportionate amounts of potash, phosphoric acid and nitrogen, so as to suit the particular crop to be grown.

Soils likewise differ in the amount of available plant food already present in them; therefore, a proper fertilizer must suit the soil as well as the crop.

A very large amount of commercial fertilizer is used within the State of Indiana, but largely without any understanding as to the needs of the soil or the requirements of the plants. Numerous experiments have been made with fertilizers on the various soil types, and very good results obtained. The following description, together with the accompanying photographs, will show the results of some of the experiments. These are in reference to the corn experiments on the farm of W. A. Hart, near Portland, Jay County.

The land is a moderately heavy clay loam which had become very badly worn through bad cropping by tenant. For the past six years which Mr. Hart has owned it the land has received heavy applications of highly steamed bone meal, which provided an abundant supply of phosphoric acid and at first gave good wheat yields and good stands of clover. The land, however, would not produce good corn, the stalks being very short and the ears small and light. Mr. Hart believed, in common with a great many other farmers, that potash was not "necessary" on this land because the soil already contained in the neighborhood of one and one-half per cent of potash. But he did not realize that this was practically all in the form of feldspar or related compounds, and about as soluble as window glass.

According to some of the theories now current in agricultural literature, his repeated turning under of clover crops and manures should have rendered enough of this insoluble potash available to produce a good corn crop. But, in fact, nothing of the kind happened, and he has never been able to produce good sound corn without the addition of soluble potash compounds. The yield on Mr. Hart's farm was increased from 40 bushels to about 70 bushels per acre.



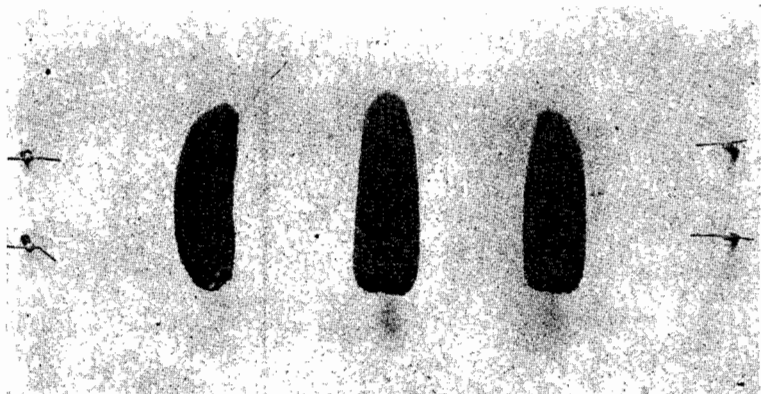
Corn grown with clover and manure as fertilizer upon the farm of W. A. Hart, near Portland, Jay County.



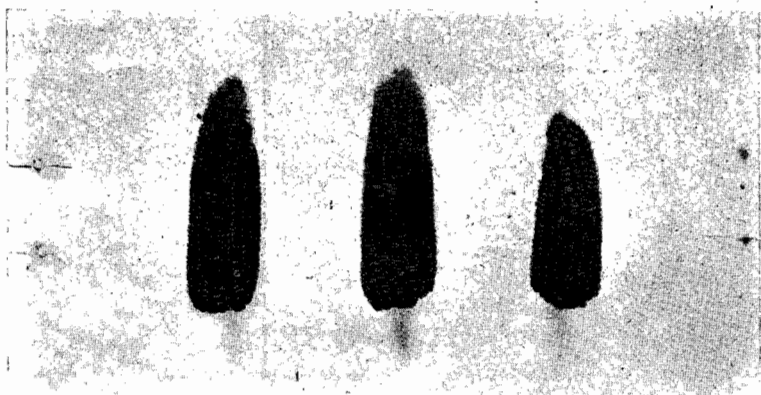
Corn grown with clover, manure and 35 lbs. sulphate potash per acre.
Increase from 40 to 70 bushels per acre.



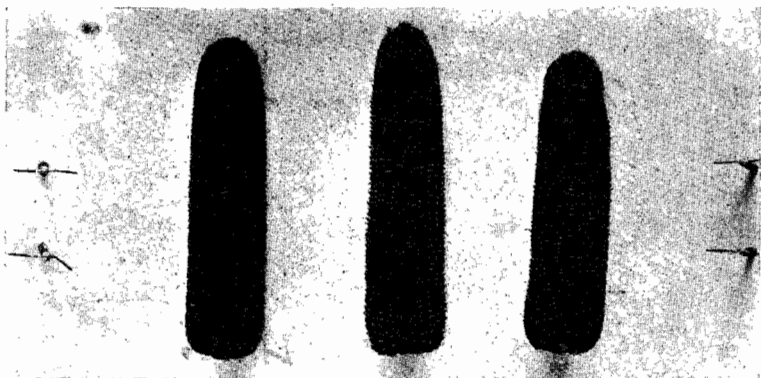
1. Corn grown with clover alone as fertilizer. 3. With clover and manure.
5. With clover, manure and 35 lbs. sulphate potash per acre.



Corn grown with clover alone as fertilizer.



Corn grown with clover and manure. The three stalks were badly broken and not used in photo as shown in lot numbered 1, 3, 5.



Corn grown with clover, manure and 35 lbs. sulphate potash per acre.

Such experimental work has been tried upon hundreds of farms with great success. Upon the reclaimed swamp lands, of which there are millions of acres in Indiana, the results are even more striking than the example given. In the case of muck lands, however, there is not even a lot of insoluble potash present. On the swamp lands it is not unusual to send the yields from nothing up to 65 or 75 bushels per acre by the application of 100 pounds of muriate of potash per acre.

The cheapening of potash as a fertilizer has rendered possible the profitable cultivation of large areas of land which were naturally too poor in that substance for ordinary productions, and has likewise rendered possible the restoration of lands that had become worn out by long-continued cropping. It also served to intensify agricultural production wherever desired, and between this supply and that of phosphoric acid and the discovery of the nitrogen absorbing power of leguminous plants, which can be used for green manuring, farmers have been enabled to dispense largely with the production and use of stable manure, which until then had been considered indispensable to agriculture everywhere.