Reclaiming Iowa's "push" soils.

L. W. Forman
Iowa State College

Follow this and additional works at: http://lib.dr.iastate.edu/bulletin

Part of the Agriculture Commons, and the Agronomy and Crop Sciences Commons

Recommended Citation
Forman, L. W. (2017) "Reclaiming Iowa's "push" soils,"
Available at: http://lib.dr.iastate.edu/bulletin/vol16/iss191/1

This Article is brought to you for free and open access by the Extension and Experiment Station Publications at Iowa State University Digital Repository. It has been accepted for inclusion in Bulletin by an authorized editor of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
RECLAIMING IOWA’S “PUSH” SOILS

The plow point will not penetrate the impervious subsoil but passes over the surface, "pushing" the top soil aside.

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS

SOILS SECTION

Ames, Iowa
SUMMARY.

1. "Push" soils are small, partially unproductive areas occurring on hillsides where the surface loess soil is shallow and a heavy, impervious clay subsoil appears near or at the surface. It is difficult to plow such spots.

2. "Seepage" spots frequently occur in connection with push soils. They are formed by the water flowing over the clay subsoil and out on the hillside where the loess covering is completely removed and the clay subsoil appears at the surface.

3. "Push" soil areas vary from one-tenth of an acre to one or two acres in size, but they occur in otherwise productive land and are, therefore, distinctly objectionable.

4. The plant food content in "push" soils is not low, but they are lacking in organic matter and acid in reaction. Phosphorus and nitrogen are generally found in sufficient amounts for good crop growth at present, but with increased crop production these elements will need to be applied.

5. Five years' results from a field experiment on a typical "push" soil area show the value of drainage, deep tillage, manuring and liming on the wheat, corn, oats and soybeans of the rotation.

6. Drainage is very essential for the reclamation of "push" soils and should be the first treatment practiced.

7. Manuring proved a most valuable treatment for the soils and farm manure is recommended for application to "push" soils especially in connection with drainage and deep plowing.

8. Deep plowing is distinctly profitable on "push" soils, as it opens up the heavy subsoil, makes more plant food available, puts the soil in a better physical condition and gives the plant roots a deeper zone for growth.

9. The use of a subsoiler would probably prove quite as satisfactory as the deep tillage machine used in this work and would be much less expensive. The purchase of deep tilling machines by individuals cannot be recommended.

10. "Push" soils can be reclaimed and made as highly productive as the surrounding land by proper drainage, deep plowing, manuring and liming.
RECLAIMING IOWA’S "PUSH" SOILS.
By L. W. Forman

Small, practically unproductive areas, known locally as “push” soils, are of rather common occurrence in some sections of southern Iowa. They are found on hillsides, usually about midway down the slope, and the name “push” soil seems to have risen because of the behavior of the soil during plowing. The surface soil is shallow and the underlying material is such a heavy, impervious clay that the plow points will not readily cut it, but tend to pass over the surface, “pushing” the thin top soil aside.

The individual areas of these “push” soils are not large, varying from one-tenth of an acre to one or two acres in size, but they are quite unproductive, usually growing nothing but a native grass which is useless for feeding, and their occurrence in otherwise productive areas, as well as the difficulty in cultivating, makes them objectionable. It is quite desirable that such spots be reclaimed, and the work reported in the following pages was undertaken to determine the best methods of making “push” soils productive.

Fig. 1. The location of a “push” soil spot on the hillside is indicated by the arrow.

The author desires to acknowledge his great indebtedness to Prof. W. H. Stevenson for directing the work, and to Dr. P. E. Brown for revising and preparing the manuscript for publication.
THE ORIGIN OF "PUSH" SOILS.

"Push" soils have been found, so far, mainly in the western part of the southern Iowa loess soil area, in Union county and in the immediately surrounding counties. They may occur elsewhere, but their presence has not yet been noted.

The southern Iowa loess soil area has a surface layer of so-called loess, a fine, dust-like material bearing no relation to the underlying formation. This covering of loess was deposited upon a layer of glacial material known as Kansan drift. This drift, when unchanged by exposure to weathering, consists of a bluish, sticky, gritty clay containing some sand, gravel, stones and small boulders. Where it is exposed, its bluish-drab color has been changed to a yellow or brown, but it remains a typical heavy, tenacious, gritty clay which in some areas is particularly impervious.

Many centuries elapsed between the laying down of the drift material and the deposits of the loess upon it and in that time much erosion occurred. The area became very rolling and even rough in some parts and this condition was not greatly changed by the loess, altho of course the deposit was thicker in the valleys than on the hillsides.

The fine loessial material is rather easily carried by water and much of it has been washed away from the steeper areas. In many places, therefore, the surface loessial soil is very thin,
or even entirely missing, and the underlying heavy, impervious Kansan drift clay is close to the surface or exposed.

It is in these places that the so-called “push” soils are found. They are, therefore, merely areas where a thin surface soil rests upon a tough, impervious clay; they are unproductive because the roots of the plants penetrate the clay subsoil with great difficulty and are unable to develop properly. Moisture and plant food are also lacking and under these conditions plants often do not make even a feeble growth.

The plow penetrates the impervious subsoil only with difficulty and tends to “push” thru the loessial covering. The soil adheres to the plow in a sticky mass which must be removed by hand, as the plow will not scour. Frequently the soil “balls” up before the plow, which is forced out of the ground.

Associated with “push” soils, there usually occur also so-called “seepage” spots which are the direct result of the former. The rainfall does not penetrate the impervious subsoil, but flows along under the surface soil and over the clay layer, until lower down the clayey subsoil appears at the surface. At that point, the water flows out and forms a “seepage” spot. The accompanying diagram, fig. 3, shows how such spots may occur. The proper use of tile is the necessary treatment for the prevention of “seepage” spots.

**PLANT FOOD CONTENT IN “PUSH” SOILS.**

To determine the plant food content of “push” soils, samples

---

![Diagram showing the location of a “push” soil area and “seepage” spot.](image)

**Fig. 3.** Diagram showing the location of a “push” soil area and “seepage” spot.
were secured from the check plots in the field experiments described later and analyses made for total phosphorus, total nitrogen, total organic carbon and limestone requirement. The phosphorus, nitrogen and organic carbon were determined by the official methods and the limestone requirement by the Truog method. The results of the analyses are given in table I. The samplings were made at two places in each plot so that four samples at each depth were secured. The actual depth of the surface soil on the various plots in the field experiment is variable, as appears in fig. 4 and the samples from plots 3 and 8 (check plots) were taken where the surface soil varied in depth. One sample from each plot, however, was secured where the soil is 2 to 3 inches in depth and one from each plot where the soil was 3 1/2 to 4 1/2 inches deep. The results, therefore, are quite representative of the total area and also of "push" soil areas in general and they are also comparable among themselves.

The phosphorus content of the samples is somewhat variable, ranging from 835 pounds in one case (No. 821) to 1,643 pounds in another (No. 311). The lower amount might be attributed to the shallow surface soil, but the larger amount was obtained from the shallower part of the other plot and hence it must be concluded that there is considerable variation in the phosphorus present in the underlying heavy subsoil. This assumption is borne out by the fact that samples taken below surface sample No. 311, high in phosphorus, showed more phosphorus than samples taken from below the other surface samples. The lower layers under surface sample No. 821, low

<table>
<thead>
<tr>
<th>No.</th>
<th>Depth</th>
<th>Total Phosphorus</th>
<th>Total Nitrogen</th>
<th>Total Organic Carbon</th>
<th>Inorganic Carbon</th>
<th>Limestone Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>311</td>
<td>0-61/2 inches</td>
<td>1,643</td>
<td>3,867</td>
<td>42,800</td>
<td>0</td>
<td>6,000</td>
</tr>
<tr>
<td>312</td>
<td>61/2-20 inches</td>
<td>2,856</td>
<td>5,240</td>
<td>51,120</td>
<td>0</td>
<td>6,000</td>
</tr>
<tr>
<td>313</td>
<td>20-40 inches</td>
<td>3,556</td>
<td>3,616</td>
<td>45,576</td>
<td>0</td>
<td>3,000</td>
</tr>
<tr>
<td>321</td>
<td>0-61/2 inches</td>
<td>1,482</td>
<td>3,250</td>
<td>33,792</td>
<td>0</td>
<td>10,000</td>
</tr>
<tr>
<td>322</td>
<td>61/2-20 inches</td>
<td>1,616</td>
<td>4,483</td>
<td>42,054</td>
<td>0</td>
<td>8,000</td>
</tr>
<tr>
<td>323</td>
<td>20-40 inches</td>
<td>2,423</td>
<td>2,774</td>
<td>30,195</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>811</td>
<td>0-61/2 inches</td>
<td>1,199</td>
<td>3,699</td>
<td>44,535</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>812</td>
<td>61/2-20 inches</td>
<td>1,616</td>
<td>4,371</td>
<td>54,452</td>
<td>0</td>
<td>2,000</td>
</tr>
<tr>
<td>813</td>
<td>20-40 inches</td>
<td>1,576</td>
<td>3,926</td>
<td>28,861</td>
<td>0</td>
<td>1,000</td>
</tr>
<tr>
<td>821</td>
<td>0-61/2 inches</td>
<td>835</td>
<td>3,110</td>
<td>38,942</td>
<td>0</td>
<td>6,000</td>
</tr>
<tr>
<td>822</td>
<td>61/2-20 inches</td>
<td>1,536</td>
<td>4,539</td>
<td>47,454</td>
<td>0</td>
<td>5,000</td>
</tr>
<tr>
<td>823</td>
<td>20-40 inches</td>
<td>1,616</td>
<td>3,531</td>
<td>35,010</td>
<td>0</td>
<td>2,000</td>
</tr>
</tbody>
</table>
in phosphorus, were also lower in the element than the other samples. The heavy clay subsoil, however, does not seem to be very noticeably deficient in phosphorus and if crops suffer for lack of that element on these soils it must be due to the fact that there is not sufficient produced in an available form. In fact, the physical conditions in the soil are so highly unsatisfactory that it would not be expected that bacterial activities would be sufficient to bring about any appreciable production of available phosphorus or of any other element.

The content of phosphorus in the surface soil of the "push" soil area, while therefore not very high, is apparently adequate in most cases to keep the crops supplied for some time. When such soils are properly handled, however, and crop production is increased, phosphorus will be removed in greater amounts, and phosphorus fertilizers will soon be needed. It is possible also that phosphorus fertilizers might be profitable in some cases now, or at least as soon as the soils are properly drained and cultivated. The variation in phosphorus content is so wide that it would seem desirable to test the value of phosphorus fertilizers on newly reclaimed "push" soils, as that is the only method by which the need and value of such materials can be definitely ascertained.

The nitrogen content of the soils is quite uniform in the different samples, not only in the surface soils but also in the lower layers. The same samples which were high and low in phosphorus were high and low in nitrogen, respectively, but the difference in the latter case was not so pronounced.

The total amount of nitrogen present is not high, but neither is it extremely low, and hence it is unlikely that crops on these soils will suffer at present from a lack of nitrogen, provided the physical soil conditions are improved so as to permit of proper bacterial activities. The element must be supplied at regular intervals, however, if the content is to be properly kept up. It can be added in considerable amounts in manure and by the use in some cases of green manures. If legumes are used as green manures and properly inoculated, as they always should be, nitrogen may be maintained economically.

The amount of organic matter present in the soils is neither extremely low nor very high. The content is very much the same in the different surface samples, but there are some variations in the lower soil layers. The sample which is high in phosphorus and nitrogen is also high in organic carbon, but there is not enough difference among the samples to warrant comparisons. It is quite evident that the organic carbon and nitrogen do not vary as much in "push" soils as does phosphorus.

The appearance of "push" soils confirms the conclusion
from the analyses that the organic matter content is not sufficient for the best crop production. Applications of organic materials would undoubtedly prove of value and farm manure is the most desirable material to use, as it not only supplies organic matter and plant food, but it also adds large numbers of bacteria which will increase available plant food. Green manures may be used in some cases to supplement farm manures, but it would be advisable to make a small application of farm manure along with the green manure in order to stimulate bacterial activities and increase the decomposition processes and the production of available plant food.

The soils are all acid, the surface soils being particularly deficient in lime. The amounts of lime required as shown by the tests vary somewhat as is always the case in different samples of soil. The lower soil layers are apparently less in need of lime, but all the samples were acid.

"Push" soils should evidently be tested for acidity and lime applied accordingly. The application of lime will aid in making plant food available by stimulating bacterial action, it will make the physical condition in the soil more satisfactory for the best crop growth, and it will neutralize the acids present or produced, which tend to restrict plant growth. When manure is applied it is particularly necessary that lime be used also, to obtain full benefits from the manure.

**FIELD EXPERIMENT ON “PUSH” SOIL.**

In order to study the needs of “push” soils and to determine if possible the best treatments, a field experiment was laid out in 1913 on a typical “push” soil area three miles east of Creston in Union county. It was planned to test the value of drainage and deep tillage and also of applications of manure, limestone and air-slaked lime.

Twelve plots were laid out, six of which (3, 4, 5, 6, 7 and 8) were one-tenth of an acre in size, four (9, 10, 11 and 12) one-twentieth of an acre and two (1 and 2) about one-twenty-first of an acre. The latter two were made somewhat smaller because of an open ditch just north of them. The four twentieth-acre plots were laid out as two tenth-acre plots, but these were divided into four plots by the application of limestone to the north half of each plot.

There were some variations in the depth of the surface soil, not only among the different plots, but also on different parts of the same plots. Depth of surface soil, of course, has considerable effect on the crop yields, but as the variations in this experiment are typical of push soil areas, the results may be considered applicable to such soils anywhere. Fig. 4 shows the surface soil depths on the various plots.
A four-year rotation of wheat, corn, oats and clover was followed and the yields of these crops are given for four seasons, 1914, 1915, 1916 and 1918. The clover crop of 1917 was winter-killed and soybeans were seeded, but owing to severe drought the yield of this crop was not obtained. The height of the crop on the various plots was determined, however, and these figures may be considered to indicate the relative yields which might have been secured. The treatments of the plots and the yields of the four crops as well as the height of the soybeans in 1917 are shown in Table II.

Plots 1 and 2 were plowed in the fall of 1913 to a depth of 18 inches with a deep tilling machine. Plot 2 received an application of mixed well-rotted manure at the rate of 12 tons per acre before plowing. Plots 5, 7, 9 and 10 received manure at the rate of 10 tons per acre and plots 3 to 12, inclusive, were then fall plowed to a depth of 6 inches. Limestone was applied at the rate of 2 tons per acre to plots 5, 6, 9 and 11 and disked into the surface soil which was in preparation for

**Table II. Crop Yields on “Push” Soil Experiment Plots.**

<table>
<thead>
<tr>
<th>Plot No.</th>
<th>Treatment</th>
<th>1914 Yield of Wheat in Bu.</th>
<th>1915 Yield of Corn in Bu.</th>
<th>1916 Yield of Oats in Bu.</th>
<th>1917 Height of Soybeans, In.</th>
<th>1918 Yield of Wheat in Bu.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Deep Tillage</td>
<td>29.3</td>
<td>50.6</td>
<td>50.0</td>
<td>10.0</td>
<td>13.6</td>
</tr>
<tr>
<td>2</td>
<td>Deep Tillage + Manure</td>
<td>49.5</td>
<td>67.3</td>
<td>80.0</td>
<td>16.0</td>
<td>36.3</td>
</tr>
<tr>
<td>3</td>
<td>Check</td>
<td>17.4</td>
<td>45.6</td>
<td>35.0</td>
<td>7.5</td>
<td>6.8</td>
</tr>
<tr>
<td>4</td>
<td>Air-slaked Lime</td>
<td>19.4</td>
<td>49.7</td>
<td>38.0</td>
<td>7.25</td>
<td>10.2</td>
</tr>
<tr>
<td>5</td>
<td>Manure + Limestone</td>
<td>41.6</td>
<td>62.3</td>
<td>75.0</td>
<td>9.5</td>
<td>20.4</td>
</tr>
<tr>
<td>6</td>
<td>Limestone</td>
<td>16.6</td>
<td>42.2</td>
<td>42.0</td>
<td>8.0</td>
<td>11.3</td>
</tr>
<tr>
<td>7</td>
<td>Manure</td>
<td>34.9</td>
<td>45.3</td>
<td>76.0</td>
<td>9.5</td>
<td>21.5</td>
</tr>
<tr>
<td>8</td>
<td>Check</td>
<td>23.1</td>
<td>33.7</td>
<td>37.0</td>
<td>8.0</td>
<td>15.9</td>
</tr>
<tr>
<td>9</td>
<td>Drainage + Manure + Limestone</td>
<td>21.9</td>
<td>48.2</td>
<td>78.0</td>
<td>9.0</td>
<td>20.8</td>
</tr>
<tr>
<td>10</td>
<td>Drainage + Manure</td>
<td>39.2</td>
<td>59.5</td>
<td>78.0</td>
<td>9.5</td>
<td>26.1</td>
</tr>
<tr>
<td>11</td>
<td>Drainage + Limestone</td>
<td>16.3</td>
<td>44.1</td>
<td>44.6</td>
<td>7.5</td>
<td>15.9</td>
</tr>
<tr>
<td>12</td>
<td>Drainage</td>
<td>16.5</td>
<td>50.9</td>
<td>43.0</td>
<td>7.0</td>
<td>13.6</td>
</tr>
</tbody>
</table>
Fig. 5. The effects of various treatments on "push" soil.

Photo by L. L. Rhodes.
winter wheat. Air-slaked lime was applied to plot 4 at the rate of 2 tons per acre and disked in as was the limestone.

Prior to plowing, a line of 3-inch tile was laid between plots 9-11 and 10-12, having an outlet into an open ditch 400 feet further down the slope. By this means the water from above is carried away under the plots and cannot appear at the surface to form "seepage" spots.

THE WHEAT CROP.

The effect of treatment became evident in some instances on the wheat crop the first year after the experiment was started. The application of 10 tons of manure alone brought about a distinct increase in yield over that obtained from the check plots. When used with limestone a still larger increase was secured, except on plot 9 where the crop yield was evidently abnormal, as will be pointed out later. The limestone alone had no effect on the wheat and the same is true of the air-slaked lime. The soil was distinctly acid in reaction, but wheat is not particularly sensitive to acidity and other soil conditions were evidently of more importance. When manure was applied the limestone did prove of benefit.

During the 1914 season there was no excess water to be carried away from the plots and hence the drainage of plots 9, 10, 11 and 12 showed no effect. These plots therefore duplicate the corresponding treatments without drainage.

The manure increased the yield, while the limestone alone had no effect. The yield on plot 9 was certainly abnormal and should not be considered, for it was lower than on the check plot adjoining it on one side and lower than the manure plot on the other side. Manure gave increased crop yields in all other cases and there is no reason why limestone should reduce the yield, hence some unknown factor must have decreased the crop growth on this plot.

Deep tillage brought about an increase in crop yield over the check plots which were plowed only to 6 inches. The deepening of the root feeding zone for the plants is apparently of considerable value. When manure was applied along with deep tillage, a large increase in wheat was secured, the yield in fact being the largest secured on any of the plots. The value of the manure was about the same as when used on the other plots and hence the beneficial influence of deep tillage is emphasized. The difference in yields due to the deep tillage was not so large, however, as to warrant the purchase of a machine.

THE CORN CROP.

The results secured with the corn crop in 1915 very largely confirm those of the previous season with the wheat. Again
the manure alone increased the crop yield, although the gain was not so pronounced as in the case of the wheat. When manure was used with the limestone, however, a very much greater increase in crop was secured. The limestone alone had a very little effect, less in fact than that shown by the air-slaked lime. Like wheat, however, corn is not particularly sensitive to acidity in the soil and other factors exert much more influence on the crop yield.

Drainage was found to be of some value in this season, somewhat greater yields being secured on the drained plots than on the corresponding undrained ones. The differences were not great, however, owing to the fact that this was the first season that the drain was needed. On similar areas in nearby fields, where tile had been installed for several years, the value of drainage was more pronounced.

Again as in the case of the wheat, plot 9 was evidently abnormal, as the yield was lower than on plot 10 where manure was applied without limestone. The cause of the abnormality in this plot is evidently disappearing, however, for the depression was not as great as in the preceding year. The limestone in addition to the manure gave a large increase in yield on the undrained plot (5) and the same effect would be expected on plot 9, if it were normal.

Deep tillage again increased the crop yield, and improved the quality of the corn, showing the value of a deeper surface soil and better moisture, aeration and plant food conditions. When manure was applied in addition to deep tillage the crop yield was very much greater. The incorporation of organic matter with the heavy subsoil when it is opened up is evidently of distinct value.

**THE OATS CROP.**

In 1916 the effects of the treatment of the plots became very distinct on the oats crop. The manure alone gave an increase of 40 bushels over the check plot. The limestone increased the yield somewhat, as did also the air-slaked lime, but the latter material gave a smaller increase than limestone. When used with the manure the limestone gave no additional effect. The drainage of plots 11 and 12 was of some value, but on plots 9 and 10 the increases from the use of manure were about the same as on the corresponding undrained plots. The rainfall during this growing season of the oats crop was very light and hence the effects of drainage were not expected to be very pronounced. Plot 9 had apparently become normal, as the yield was about the same as on plot 10.

Deep tillage again showed a distinct increase over the check plot, and when manure was applied also, there was a large in-
crease in crop yield. The increase, however, was about the same as from the manure alone on the plots plowed to 6 inches. As in the case of the other crops, manure showed a large effect on the oats and deep tillage also proved of value.

THE SOYBEAN CROP.

As the yield of soybeans was not secured, owing to the drought, and only the height of the crop was obtained, it is hardly possible to reach any definite conclusion regarding the value of treatment. It would seem, however, from a consideration of the figures, that manure exerted some effect on the crop. This is in accord with the preceding results and shows the persistent influence of manure throughout a four-year rotation. Limestone had no appreciable effect and the same is true of the air-slaked lime. Lime should exert some influence on the growth of a legume in an acid soil, and possibly the yields would have shown an effect which was not apparent in the height of the crop.

Very little rain fell on the plots during May and throughout the season the moisture content of the soils was very low. The tile drains were, of course, not called into use during the entire season and hence drainage showed no effect.

Deep tillage alone exerted considerable influence on the growth of the soybeans, as measured by the height of the crop. When manure was applied the effect of the deep tillage was even more evident, the crop being more than twice as tall as on the check plots. This is again in accord with the results secured with the first three crops in the rotation.

THE WHEAT CROP—1918.

Owing to the extremely dry weather during the latter part of 1917, it was considered undesirable to plow the plots in preparing for the winter wheat, and the seed bed was prepared by thoroughly disk ing. The applications of manure were made to the proper plots in the same amounts as the first year of the experiment and thoroughly disked in.

The wheat was badly winter-killed on the plots where no manure was added, and especially on plot 4, where the crop was thin and the foliage yellow. The wheat also stool ed much more on the manured plots. The crop yields on the manured plots were, therefore, much larger.

Limestone and air-slaked lime again showed no effect on the wheat crop. The rainfall during the growing season was about normal and hence the effect of drainage was evident. The treated plots which were drained showed greater yields than similar untreated plots and the drained plots which were untreated showed a slight increase over the check plots.
Deep tillage still had some effect on the wheat crop, five years after it had been practiced, altho the increase was small. With manure, however, the yield on the deep tillage plot was much increased. The gain in crop was over twice as great as with manure alone on the shallow tilled plots.

The results as a whole for the second wheat crop in the rotation confirm in every particular the effects of the various treatments, as shown during the first rotation. The beneficial influence of manure, deep tillage and drainage is very apparent, manure being most effective with deep tillage.

**THE MANAGEMENT OF “PUSH” SOILS.**

**DRAINAGE.**

The first treatment necessary to reclaim “push” soils, and especially to prevent the formation of “seepage” spots, is the installation of an adequate drainage system. Tile should be laid around the “push” soil spots and across the hill above the spot in a line at right angles to the slope of the hill. In this way the water from above is carried away and prevented from coming to the surface to form a “seepage” spot. The tile should be laid on the impervious subsoil just below the surface soil, wherever possible, care being taken, however, that it is laid deep enough not to be injured by frost. When the surface soil is very shallow, it may be necessary to place the tile below the surface of the clay, in which case it should be blinded in with coarse cinders or broken stone. If the “push” soil area is small, the ditch should then be filled with soil other than that which was removed. If a large area is involved, however, the soil which was removed may be used to fill the ditch, but in this case it is advisable to fill to the surface with cinders or stones at intervals of 6 or 8 rods. The areas so filled should be 5 or 6 feet in length.

![Diagram of tile laying](http://lib.dr.iastate.edu/bulletin/vol16/iss191/14)
The tile should be provided with a good outlet further down the slope. This is not difficult, as the topography of the areas where “push” soils occur is uniformly rolling.

In case the spots are more than one-tenth to one-fifth of an acre in size, it is advisable to lay branch lines of tile directly thru the area in lines parallel to the slope of the hill and connected with the main line. The number of such branch lines will depend, of course, upon the size of the area and the adequacy of the drainage. The accompanying figure (Fig. 6) will illustrate the laying of tile around the “push” soil spots and the placing of laterals or branch lines.

**APPLICATION OF FARM MANURE.**

The application of farm manure to “push” soils is distinctly profitable, according to the results of the experiments reported in the preceding pages. These soils are uniformly low in organic matter and the best means of increasing the amount of that material is to apply farm manure. The physical condition of “push” soils, especially of the heavy subsoil layer, is decidedly unsatisfactory and organic matter aids in opening up such a soil and putting it in a better physical condition for crop growth. The benefit secured from applying manure to the deep tillage plots is a definite evidence of the importance of improving the mechanical condition of the clay subsoil which underlies “push” soils. Manure has an additional value, however, in that it improves the water-holding power of the soil and this effect is very important where the surface soil is shallow and dries out very quickly, as is the case on “push” soil spots. The beneficial effect of manure alone on the shallow tilled plots is largely due to the improved moisture conditions.

Manure does more than add organic matter to soils, however. It supplies considerable amounts of plant food, nitrogen, phosphorus and potassium. “Push” soils are not high in plant food, due mainly to their shallowness, and crops may be benefited materially by the plant food in manure. The actual addition of plant food is probably a second reason for the increase in crops secured by the application of manure to the shallow tilled plots and also to the deep tilled plots.

Finally, the bacterial content of manure is undoubtedly largely responsible for the good effect of manure on “push” soils. The subsoil material which is opened up in the deep tillage operation contains some plant food, but it is not in a form to be used by plants and if it is to be taken up by them it must be made available. The bacteria in the manure play a part in bringing this store of plant food into a condition in which plants can utilize it and crops are benefited accordingly.
The use of manure on “push” soils is, therefore, strongly to be urged. It should be applied in normal amounts, that is, from 8 to 10 tons per acre, or possibly 12 tons per acre. The physical, chemical and bacteriological conditions in the soils will be improved and crop growth accordingly increased to a profitable extent by such applications.

In case farm manure is not available, green manure may possibly be used instead. These experiments did not include the test of green manure and hence definite recommendations along this line cannot be made. It is true, of course, that green manures would not add bacteria as farm manure does, but they supply organic matter which is so important as a means of improving the physical conditions in the soil and, if legumes are used, they will also supply nitrogen, provided, of course, that they are well inoculated. It may be that these two effects would be sufficient to make the soil properly productive.

DEEP PLOWING.

Deep plowing on “push” soils is of undoubted value. When the heavy subsoil is opened up, and especially when manure is incorporated with it, large increases in crop yields and in stalk and straw growth are secured. A greater zone of action for the plant roots is provided, moisture and air conditions are more satisfactory and plant food in an available form is produced in a much greater quantity. The application of manure to the clay subsoil when it is opened up is valuable because of the organic matter, plant food and bacteria, which it introduces. The organic matter aids in bringing the clay into a better physical condition, the plant food in the manure supplements that in the soil and the bacteria bring about a greater production of available plant food not only from the manure itself, but also from the stock contained in the soil.

In this work a deep tilling machine was employed in opening up the heavy subsoil, but it is quite probable that subsoiling would be equally valuable. Deep tilling machines are very expensive and their purchase by individual farmers should not be recommended as an economical proposition. They might be secured by groups of farmers or by farm bureaus, however, and thus the expense involved would be divided so that the cost to each individual would not be large. The subsoiler costs less than one-tenth as much as the deep tilling machine and it will probably bring about the opening up of the subsoil quite as satisfactorily. Unfortunately this method of plowing was not tested in the experiment, but from general experience elsewhere with subsoiling the conclusion seems warranted that it would prove very valuable on “push” soils.