Loss of Soil Organic Matter and Its Restoration

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CENTURIES before there was any science that acquainted people with the intricacies of plant nutrition, decaying organic matter, as in manure or other forms, was recognized as an effective agent in the nourishment of plants. The high productivity of most virgin soils has always been associated with their high content of organic matter, and the decrease in the supply with cultivation has generally been paralleled by a corresponding decrease in productivity. Even though we can now feed plants on diets that produce excellent growth without the use of any soil whatever, yet the decaying remains of preceding plant generations, resolved by bacterial wrecking crews into simpler, varied nutrients for rebuilding into new generations, must still be the most effective basis for extensive crop production by farmers. Soil organic matter is one of our most important national resources; its unwise exploitation has been devastating; and it must be given its proper rank in any conservation policy as one of the major factors affecting the levels of crop production in the future.

The stock of organic matter in the virgin soils taken over by the homesteading pioneers was a heritage from an extensive past. Its accumulation in our northern soils began with the recession of the last glacier, possibly some 25,000 years ago, and continued long enough to ripen the residues into compounds that were ready to be used quickly by growing plants.

With the departure of the ice sheet and the consequent general rise in temperature, the glacial residue of pulverized rock offered minerals in solution for plant growth. As the plants found nitrogen to combine with these minerals, they grew, died, and began to accumulate in the soil. Then, as the rate of rock weathering increased, bringing a larger supply of soluble minerals, the accumulation of plant remains became correspondingly larger. Finally, when the rocks were more completely weathered so that they provided less mineral stock, or very little, an equilibrium point was reached at which the accumulated organic matter held in combination most of the minerals that could be turned into soluble forms. Thereafter the supply of soluble minerals became a limiting factor in plant growth.

Wherever there was poor drainage and limited aeration of the sod cover, or where there were heavily wooded soils of relatively level, glaciated topography, more complete simplification of this accumulated store of plant nutrients was very slow. In other words, the organic matter that held the major stock of previously mobile nitrogen and minerals now kept these essentials stored in compounds not simple enough for prompt consumption by growing plants. This represented a very large supply of nutrients not far from the condition in which growing plants could use them. Unable to decay completely or to accumulate much more, they were poised as it were for rapid conversion, when a slight change in conditions occurred, into forms of maximum utility for plant growth.

But with the removal of water through furrows, ditches, and tiles, and the aeration of the soil by cultivation, what the pioneers did in effect was to fan the former simmering fires of acidification and preservation into a blaze of bacterial oxidation and more complete combustion. The combustion of the accumulated organic matter began to take place at a rate far greater than its annual accumulation. Along with the increased rate of destruction of the supply accumulated from the past, the removal of crops lessened the chance for annual additions. The age-old process was reversed and the supply of organic matter in the soil began to decrease instead of accumulating.

Fuel for the Plant-Food Production Factory

Organic matter may well be considered as fuel for bacterial fires in the soil, which operates as a factory producing plant nutrients. The organic matter is burned to carbon dioxide, ash, and other residues. This provides carbonic acid in the soil water, and the solvent effect of this acidified water on calcium, potassium, magnesium, phosphates, and other minerals in rock form is many hundreds of times greater than that of rain water. At the same time the complex constituents of the organic matter are simplified, and nitrogen in the ammonia is released and converted into the nitrate form. This, very briefly, is the complicated process of decomposition, from which carbon dioxide results as the major simplified end product, together with a host of others in smaller amounts. This gas is released in such large quantities from the soil that the supply in the atmosphere over the earth is maintained at a constant amount.

Decomposition by micro-organisms within the soil is the reverse of the process represented by plant growth above the soil. Growing plants, using the energy of the sun, synthesize carbon, nitrogen, and all other elements into complex compounds. The energy stored up in these compounds is then used more or less completely by the microorganisms whose activity within the soil makes nutrients available for a new generation of plants. Organic matter thus supplies the "life of the Soil" in the strictest sense.

When measured in terms of carbon dioxide output, the soil is a live, active body. An acre of the better Corn Belt soil in Iowa *(365)* or northern Illinois, for example, exhales more than 25 times as much of this gas per day as does an adult man at work. Such a soil area burns carbon at a rate equivalent to 1.6 pounds of a good grade of soft coal per hour. The heat equivalent evolved in the same time would convert more than 17 pounds of water to steam under 100 pounds pressure. A 40-acre cornfield during the warmer portion of a July day is burning organic matter in the soil with an energy output equivalent to that of a 40-horsepower steam engine; every acre, in other words, may be roughly pictured as a factory using the equivalent of 1 horsepower. Organic matter is the source of the power without which the plant-food elements could not be changed to usable forms.

Supply of Virgin Soil Organic Matter Decreasing

The depletion of the supply of organic matter by cultivation is well illustrated by the report of a study made by Jenny *(185)* in central Missouri in which an undisturbed virgin prairie soil was compared to an adjoining field cropped to corn, wheat, and oats for 60 years without the addition of manure or fertilizer. No erosion had taken place, yet 38 percent of the organic matter represented by the virgin soil had been lost during that period because of cultivation. As a consequence of this loss in organic matter, the soil structure was modified to an extent that might be represented by reducing the number of granules that were the size of particles of sand by 11 percent and increasing the number that were the size of clay particles by 5.5 percent. The loss of organic matter represents soil compaction, which hampers the circulation of air and water and hinders tillage operations at the same time that the function of the soil in plant nutrition is disturbed. Thus in but 60 years, more than one-third of the organic matter, representing centuries of accumulation, was destroyed and the efficiency of the soil for crop production was reduced.

Resulting Loss in Nitrate Nitrogen

Soil organic matter is the source of nitrogen. In the later stages of decay of most kinds of organic matter, nitrogen is liberated as ammonia and subsequently converted into the soluble or nitrate form. The level of crop production is often dependent on the capacity of the soil to produce and accumulate this form of readily usable nitrogen. We can thus measure the activity that goes on in changing organic matter by measuring the nitrates. It is extremely desirable that this change be active and that high levels of nitrate be provided in the soil during the growing season.

A study of the nitrate levels under corn in a Missouri silt loam during 13 years reveals a gradual decline in the production of nitrates *(5)*. During the first 5 years of the test this soil increased its nitrates in the spring to the maximum of more than 20 pounds per acre as early as May. During a similar period only 2 years later, this maximum had been reduced to 18 pounds, and it was not attained until June; 3 years later the maximum was less than 16 pounds, attained in July; and 3 years after that, the maximum of 13 pounds was not reached until August (fig. 1). During continuous cropping to corn without the addition of organic matter, the maximum nitrate accumulation dropped to 65 percent of that in the initial period, when the land had been in sod for some time. In other words, though this soil had been in corn continuously for only 13 years--which might seem equal to 52 years of a 4-year rotation, with one crop of corn every 4 years-- its nitrate-producing power, or its capacity to deliver this soluble plant nutrient, had been reduced by 35 percent.

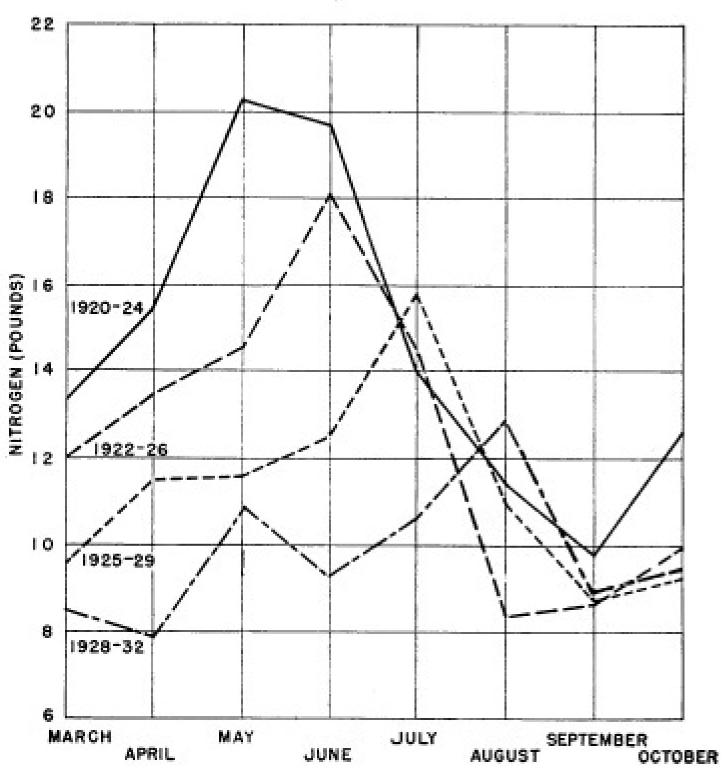

FIGURE 1.--Declining seasonal levels of nitrates and later seasonal maxima with continued cropping to corn. (Averaged for different succeeding 5-year periods.)

Such pronounced exhaustion is not limited to the corn crop, which is readily associated with intensive tillage. The same thing is true in the case of wheat. Its exhausting effects measured in the same study *(5)* and shown in figure 2, were even greater than those of corn. The nitrate level under wheat was constantly lower than under corn for the corresponding period.

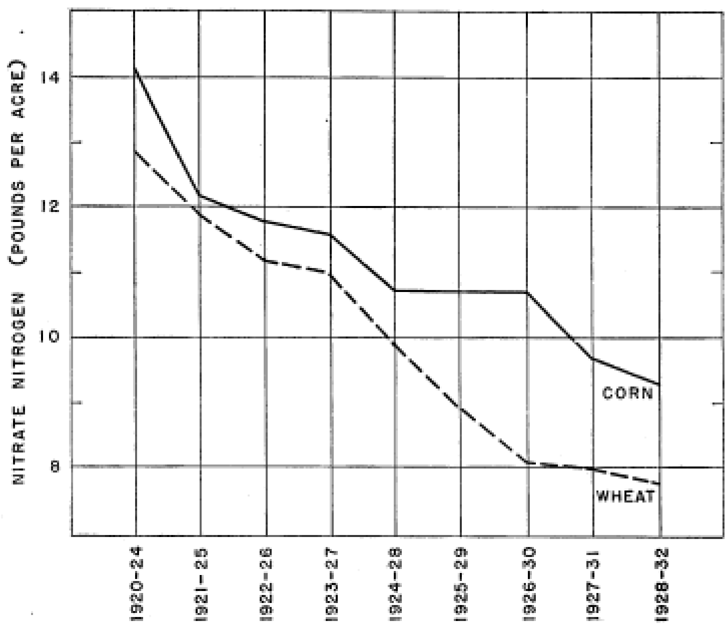

FIGURE 2.--Declining nitrate nitrogen levels in soils in wheat and in corn as advancing 5-year season averages.

Concurrently with the foregoing measurements showing the decline of nitrates, careful chemical analyses were made of the same kind of soil nearby under fallow conditions with an annual spring plowing. The surface soil alone lost 2,300 pounds of organic matter per acre, as shown in figure 3 *(4)*. A nearby plot in a 3-year rotation of corn, wheat, and clover, with all the crops removed during a period beginning 2 years earlier and extending 2 years longer--a total of 17 years--lost 800 pounds of organic matter. [Footnote:] From unpublished data supplied by M. F. Miller Missouri Agricultural Experiment Station. Regardless of the presence or absence of a crop, the failure to add organic matter and regular tillage of the soil mean a depletion of the original stock of organic matter at a very significant rate, even where there is no erosion. Where erosion removes the body of the surface soil itself, the rate of depletion is much greater.

Lower Crop Yields and Land Values

In addition to carrying nitrogen, the nutrient demanded in largest amount by plants, soil organic matter either supplies a major portion of the mineral elements from its own composition, or it functions to move them out of their insoluble, useless forms in the rock minerals into active forms within the colloidal clay. Organic matter itself is predominantly of a colloidal form resembling that of clay, which is the main chemically active fraction of the soil. But it is about five times as effective as the clay in nutrient exchanges. Nitrogen, as the largest single item in plant growth, has been found to control crop-production levels, so that in the Corn Belt crop yields roughly parallel the content of organic matter in the soil *(184)*. On a Missouri soil with less nitrogen than that corresponding to 2 percent of organic matter (40,000 pounds of organic matter per acre of plowed surface soil) an average yield of 20 bushels of corn per acre can hardly be expected. For yields approaching 40 bushels, roughly double the amount of organic matter is required. With declining organic matter go declining corn yields and therefore lower earnings on the farmers investment. Thus the stock of organic matter in the soil, particularly as measured by nitrogen, is a rough index of land value when applied to soils under comparable conditions. According to studies in Missouri, for example, the lower the content of organic matter of upland soil, the lower the average market value of the land.

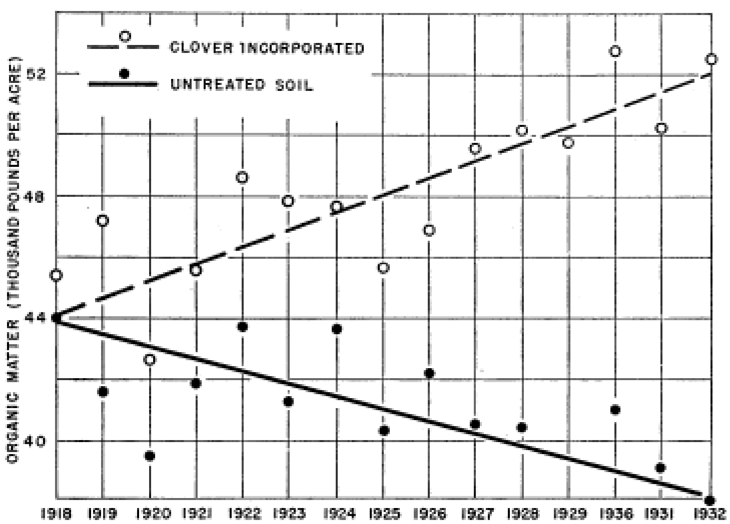

FIGURE 3.--Decrease of organic-matter content in a fallow, untreated soil in contrast to the gain in soil treated with 2 1/2 tons of red clover annually, representing over 500 pounds annual increase in organic matter per acre.

Problem of Maintaining a Liberal Supply of Soil Organic Matter

Though the rapid depletion in the Corn Belt, for example, of the soil organic matter and soil fertility in the pioneer period of a hundred years may be alarming, there is consolation in the fact that this high rate of depletion will not continue. As is true for all biochemical processes, the early rate of consumption is rapid, which gives a sudden decrease. Then the rate of consumption falls off, so that the loss in the second period will perhaps be less than half that in the first. In the third stage the loss will possibly be half that of the second. Long-continued experiments, accompanied by soil analyses, prove that the organic-matter content of a soil will reach a fixed level characteristic of the surrounding climatic conditions. After a period of heavy loss, then, we may expect a fairly constant level during a long period of continued cultivation. This situation is well illustrated by the decline in nitrogen content shown in figure 5 of the article, Soil Nitrogen (p.369). In other words, we may anticipate a further decline in productivity from the present relatively high levels, followed by a more constant level, which will be proportionate to the lower content of organic matter, determined by the environment in each particular region.

Maintaining Versus Increasing the Organic Matter

The following questions naturally arise: What should be the content of organic matter in a soil? Should the present level be raised or merely maintained economically? These are questions of decided significance in determining policies in soil management.

Attempting to hoard as much organic matter as possible in the soil, like a miser hoarding gold, is not the correct answer. Organic matter functions mainly as it is decayed and destroyed. Its value lies in its dynamic nature. A soil is more productive as more organic matter is regularly destroyed and its simpler constituents made usable during the growing season. Its mere presence in the soil is of value during certain stages of decay, when it influences soil structure and water relations and when it functions in holding plant food in readily available form much more effectively than does any mineral fraction of the soil. The objective should be to have a steady supply of organic matter undergoing these processes for the benefit of the growing crop. Up to the present, the policy--if it can be called a policy--has been to exhaust the supply, rather than to maintain it by regular additions according to the demands of the crops produced or the soil fertility removed. To continue very long with this practice will mean a further sharp decline in crop yields.

The level of organic-matter content to be maintained is not the same for all regions. It varies according to climate. Professor Jenny in his studies of virgin organic matter of soils *(184)* has pointed out that--within regions of similar moisture conditions, the organic matter content of upland, terrace, and bottomland soil, including both prairie and timber vegetation, decreases from north to south. For each fall of 10° C. (18° F.) in annual temperature, the average organic matter content of the soil increases two or three times, provided the precipitation-evaporation ratio is kept constant.

Thus from south to north the level of organic matter in the soil becomes naturally higher. In the northern section of the Temperate Zone with its moderate rate of vegetative growth and moderate production of organic matter, the longer periods of lower temperature lessen decay and increase accumulation by carry-over from season to season. In the southern section, even though the growing season is longer and produces more vegetation, yet there is also a longer season for decay, and it proceeds at a much more rapid rate. Because the rate of decay doubles and trebles for every rise of 10° C. (18° F.) in temperature, the destruction of organic matter is more complete and there is little accumulation. Its nature, particularly its composition, is also different. It shows a narrower carbon-nitrogen ratio *(184)* and a greater resistance to further simplification.

The level of organic matter in the soil of the temperate regions rises with lower annual temperatures, and also with increased moisture. The level is also higher in grasslands than in timbered soils under equal moisture conditions. The same amount of moisture in the North with its lower temperature is more effective in bringing about an increase of soil organic matter than in the South with its higher temperature. Hence sod crops are more effective restorers of organic matter in the northern than in the southern part of the North Temperate Zone. The climate of the region must be considered in determining the level of organic matter to be maintained in the soil. Changes in altitude must also be considered insofar as these correspond to climatic variations.

In northern Missouri, for example, virgin soils are in a condition of natural equilibrium at an organic-matter content of 3.54 percent; in southern Missouri at 2.20 percent; in southern Minnesota at 4.44 percent; and in Arkansas at 1.96 percent. In terms of pounds per plowed acre, the figures are: For southern Minnesota, 88,800 pounds; northern Missouri, 70,800 pounds; southern Missouri, 44,000 pounds; and Arkansas, 39,200 pounds. These figures represent the natural equilibrium between the production of organic matter by native vegetation and its destruction by micro-organisms. The balance figure is determined in the main by the temperature-rainfall combination, or climate. It would be folly, according to these data, for the farmer in Arkansas to attempt to increase organic matter in his soil to the level common in the soil tilled by the Minnesota farmer. Likewise the problem of increasing the organic matter will be simpler for the farmer in the North, where even with the same amount of moisture, the lower temperature is influential in preserving more of the organic matter added to the soil.

Cultivation of the soil and extended periods without a vegetative cover decrease the content of organic matter below that considered natural, or virgin, for the locality. The degree of exhaustion of organic matter to levels below the virgin stock represents the possibilities of improvement. But these possibilities also are affected by climate. In the northern sections both temperature and moisture conditions are favorable to restoration, and the growing of legumes and the addition of green manure are very effective in this direction, as experimental results demonstrate. Farther south, restoration is more difficult, and it may even be impossible to restore the organic matter profitably and permanently to levels even approaching virgin conditions. However, the longer growing season permits two crops a year, one of which may be a legume for green manure, and this makes it possible to provide organic matter and a turn-over of nitrogen regularly even when the level cannot be raised.

We are confronted, then, by three facts: (1) The stock of organic matter in the soil is being exhausted at an alarming rate; (2) the exhaustion is still in its early stages in some of the more recently developed agricultural areas; and (3) there are no climatic handicaps that prohibit restoration. These facts mean corresponding--and inescapable--responsibilities. The Nation should be made aware of the rapid rate at which the organic matter in the soil is being exhausted. Farm-management practices should be adopted that will at least maintain, and in as many cases as possible even increase, the supply of this natural resource in the soil. The maintenance of soil organic matter might well be considered a national responsibility.

Interrelation of Soil Organic Matter with Nitrogen and Minerals

At first thought, the problem of restoring soil organic matter may not seem difficult according to simple mathematical calculations. If a soil in virgin condition contained 44,000 pounds of organic matter per acre and 35 percent of this has been exhausted during 60 years of cultivation, the apparently simple solution would be to add 15,400 pounds of dry material to the soil, or an amount of organic matter equivalent to the weight lost. The addition of the equivalent of some 7 3/4 tons of dry matter in the form of manure, legumes, straw, and other farm-waste products might seem to be a satisfactory solution. But the virgin organic matter that has been lost was very different in nature and effects from the material considered to replace it. In kind and composition, the organic matter used for restoration should be as close as possible to that which was lost, at least in terms of effective results.

Building Soil Organic Matter Largely a Nitrogen Problem

Soil bacteria, the agents of decomposition, use carbon mainly as fuel and nitrogen as building material for their bodies and for the production of the intricate organic compounds that result from their activity. Fresh organic matter is characterized as a rule by a large amount of carbon in relation to nitrogen. It has a wide carbon-nitrogen ratio, in other words; or so far as the bacteria are concerned, a wide ratio of fuel to building material. Such fresh material--straw, for example--may have a ratio that is too wide, so that it decomposes very slowly. If the ratio is less wide, decomposition may be more actively carried on. The carbon will then be rapidly used up as fuel while the nitrogen is held or treasured without appreciable loss.

Thus when decay has proceeded to the point where the carbon-nitrogen ratio is significantly decreased, a residue of a more stable nature is produced. Thereafter the carbon-nitrogen ratio is narrower and remains more constant. This corresponds more nearly to the condition that holds in the case of the organic matter in virgin soils. Its further decay, which is slow because of the relatively low level of carbon, liberates nitrogen in place of storing or preserving it. Because of its high carbon content, the decomposition of fresh organic matter requires additional soluble nitrogen to be used as building material by the micro-organisms, which obtain it from the soil, often exhausting the supply to a degree that is damaging to a growing crop. The amount of increase in organic material corresponds, in the main, to the amount of nitrogen available. The extra carbon in the fresh material is lost from the soil. Thus when soils are given straws, fodders, and similar crop residues of low nitrogen content, only small increases in soil organic matter can result--in the main, only as large as the added nitrogen will permit. Many tons of common farm residues and wastes per acre are needed to produce a single additional ton of organic matter in the soil.

The restoration of soil organic matter, then, is a problem of increasing the nitrogen level or of using nitrogen as a means of holding the carbon and other materials. This is the basic principle behind the use of legumes as green manures. In building up the organic content of the soil itself, it will often be desirable to use legumes and grasses rather than to add organic matter, such as straw and compost, directly. If legumes and grasses are to be successfully grown on many of the soils of the humid regions of this country it will be necessary, first, to properly fertilize and lime the soil. Legumes use nitrogen from the air instead of the soil, and thus serve to increase the amount in the soil when their own remains are added to it. Commercial nitrogen used as treatment on straw for the production of artificial manure in compost piles, or when plowing under straw in the field after the combine, may be considered in the same category. Small amounts of added nitrogen may in this way make possible the use of large amounts of carbonaceous matter in restoring the soil. Thus the European farmer first "makes" his manure by composting the fresh straw-dung mixture from the barn and then treats it intermittently with the nitrogen-bearing liquid manure or urine from the same source and the nitrogen-rich leachings from the manure pit. He does not consider the fresh, strawy barn waste manure in the strictest sense until the surplus carbon has been removed through the heating process, and the less active manure compounds become similar to those of the soil organic matter. In a similar way, it should be understood that the soil organic matter can be "made" or built up only as the nitrogen supply is raised and combined with carbonaceous material in a more narrow ratio.

It is only under conditions of this kind that beneficial effects on crops may be expected through further decomposition. The manure making of the Old World farmer turns the miscellaneous straw-dung-urine mixture, of highly variable value, into a standardized fertilizer for specific use. Our great variety of crop wastes--straw, cornstalks, etc.--should be used in a similar way, by adding nitrogen to bring about a proper adjustment with their excess carbon. These neglected wastes will then provide extra and valuable soil organic matter that will have beneficial rather than possibly detrimental effects on crops.

Level of Minerals in Soil Influences Organic-Matter Supply

Bacterial activity does not occur in the absence of the mineral elements, such as calcium, magnesium, potassium, phosphorus, and others. These, as well as the nitrogen, are important: Recent studies show that the rate of decomposition is reduced when the soil is deficient in these elements. In virgin soils high in organic matter, these elements also are at a high level, and are reduced in available forms as the organic matter is exhausted. A decline in one is accompanied by a decline in the other.

It has been held that calcium, for example, is instrumental in retaining the organic matter in a stable form in the soil. Though this seems doubtful in view of the fact that the addition of lime to soils hastens the rate of loss of organic matter, calcium has a decided influence on the growing crop and therefore on the amount of material it adds to the soil when turned under. It has recently been discovered that the fixation of nitrogen from the atmosphere by legumes is more effective where high levels of calcium are present in available form *(3)*. Thus, if in calcium-laden soils, excellent legume growth results and correspondingly large nitrogen additions are made, such soils may be expected to contain much organic matter. Liberal calcium supplies and liberal stocks of organic matter are inseparable. The restoration of the exhausted lime supply exerts an influence on building up the supply of organic matter in ways other than those commonly attributed to liming.

In the presence of lime (calcium) the legumes use other elements more effectively, such as phosphorus *(175)* and probably other nutrients. Thus heavier production results on soils rich in minerals, including more intensive and extensive root development--the most effective means of introducing organic matter into the soil. The presence of large supplies of both organic matter and minerals points clearly to the fact that the soils were high in the latter when the former was produced. It seems logical to ascribe causal significance to the minerals in the production of organic matter, whether or not they are effective in preserving it. If the soils that have lost their organic matter are to be restored, the loss of minerals, which has probably been fully as great, must be taken into account, and provision must be made to restore these mineral deficiencies before attempting to grow crops for the sake of adding organic matter.

How Can Soil Organic Matter Be Restored?

Conservation and restoration of soil organic matter as a national problem calls for a program of soil and farm management in which (1) needless losses are eliminated or reduced to a minimum, and (2) the stock in process of consumption is regularly maintained with attention to its possible economical increase. Experimental results indicate the steps in such a program.

First attention should be given to eliminating accelerated erosion. When, according to the long-continued soil erosion studies at the Missouri Agricultural Experiment Station *(263),* the entire plowed surface soil under continuous corn may be washed away in 50 years, it would be foolhardiness to attempt soil building by processes so slow as to make only an inch in hundreds of years. Erosion can be eliminated, as the investigations have shown and recent extensive erosion-control experience demonstrates, by sod cover crops, reduction in the amount of tillage, and other measures. The establishment of sod crops on badly eroded land often requires proper fertilization and liming.

Sod crops have not been fully appreciated. Grasses have been the stepchildren in the American crop family. They have not been "cultivated" in the same sense as farm crops; they have been left to themselves, to grow on soils often turned over to them because depleted fertility made cereal cropping unprofitable. They have been incidental in the farm program. Consequently, they have not delivered their maximum in animal production and have often been very inefficient feed. Land in grass was considered idle and checked off the accounts, even if not recorded on the debit side.

The Old World, with its longer agricultural experience, shows that the lands still in good production today are those occupied by sod crops regularly for a large part of the time, where clean, or summer, cultivation has been reduced to a minimum. In France and England only slightly more than one-fourth of the cultivated soils are in clean cultivation. In Germany the figure is even less, and there are vast acreages of permanent pastures in all these countries. In the United States the area in clean cultivation and row crops approaches one-half the cultivated land; and this in regions where the rains are of torrential nature. We may well be guided by Old World experience, which tells us that sod crops are a paramount factor in holding the soil and maintaining its productivity by their regular additions of organic matter. The tough sod slice should be more fully appreciated as an asset in terms of its organic matter rather than considered as a liability because of the high power required to plow it.

Some recent studies suggest that we have not appreciated sod crops in relation to moisture absorption and the storage of moisture in the subsoil. The beneficial effects of sods turned under for corn crops have usually been ascribed to nitrogen, when possibly the important factor has been accumulated moisture in the subsoil. Grass crops absorbed 87.4 percent of the rainfall, a 3-year rotation with one sod crop absorbed 85.5 percent, while continuous corn absorbed only 69.6 percent, according to trials extending over 14 years *(263).* This amounted to an increased rainfall of 7.2 inches for grass and 6.4 inches for rotation as compared to continuous corn. The difference in crop yield was more significant than these figures indicate, since two-thirds of the annual rainfall came in the 6 months of the growing season, or the period when differences in rainfall mean increased yields.

Much of the extra water absorbed moves beyond the zone of consumption by the shallow grass roots and is stored there. Thus the deeper soil layer under sod, such as the third foot, carries more water than the same layer under tilled soil. Moisture studies of two such adjacent soils, no far distant from those under the erosion study cited above, are interesting from this standpoint, especially for the years 1934 and 1936, which were seasons of deficient rainfall. Table 1 gives the moisture content as the percentage of moisture in the successive 1-foot layers to a depth of 3 feet.

Table 1. Moisture content at successive depths under sod and under cultivated soil

Year and month	First foot		Second foot		Third foot	
	Sod	Tilled	Sod	Tilled	Sod	Tilled
1934:	Percent	Percent	Percent	Percent	Percent	Percent
April	27.18	25.23	29.90	24.61	26.11	16.51
November	33.80	31.70	31.90	30.80	32.60	24.80
1936:						
March	26.30	27.80	28.20	28.90	28.30	23.00
November	27.00	26.80	28.50	27.30	27.80	19.80
1937:						
April	32.90	28.30	30.00	28.60	30.70	23.40

The third-foot layer was much drier under the tilled soil than under the sod during all of these studies. Its recovery of moisture after rain was always delayed and its total water content never equaled that in the third foot under sod. Though the first-foot layer under sod had a lower moisture content than that under tillage during 1 month (March 1936), in all samplings the moisture supply of the second- and third-foot layers was greater under the sod than under the tilled surface, with the most pronounced differences in the third foot, varying from 5.3 to 9.5 percent. These differences mean on the average that the third-foot layer under sod is storing the equivalent of a 1.2-inch rainfall, which it may supply to the sod crop, or to the deeper roots of the following crop, in the drier summer season. This stored moisture under sod should be considered as a factor in combating droughts.

The advantages of grass-sod crops as effective agencies for soil restoration may be summed up as follows: They do much toward guaranteeing a moisture supply for their own needs by absorbing more of the rainfall. They add a heavy root growth annually that, for native bluestem, for example, amounts to as much as 1.34 tons per surface acre-foot, according to Weaver and Harman *(453)*. Because of the annual death of part of these roots, this is a regular addition of organic matter that helps to maintain the supply. On the untilled and less violently aerated soil, where the higher moisture means lower temperatures, these conditions favor a return to the original, or virgin, stock of organic matter in the soil. At the same time, erosion is prevented both by the living grass and by the spongy surface residue accumulated above the soil from the dead plant tops of the previous season.

Sod crops are sufficiently effective in restoring soil organic matter to offset the destructive influences of clean cultivation and summer tillage. Unpublished data from studies by the Missouri Agricultural Experiment Station show clearly the destructive influence of summer fallow and, in contrast, the increase in organic matter obtained through sod crops. When sod was used in an ordinary 3-year crop rotation, with manure made from the crops returned to the soil, there was no serious decline in the content of organic matter, as shown by table 2.

Table 2.--Gains and losses in soil organic matter (in pounds per acre of surface soil) during 17 years, on areas under different systems of cropping and management *

Crop and management	Gain	Loss
	Pounds	Pounds
Rotation--corn, wheat, clover--all crops removed	-----	800
Rotation--corn, wheat, clover--manure equivalent returned	3,200	
Rye and cowpeas--turned under as green manure	1,200	
Rye turned under--summer fallow	-----	14,400
Red clover continuously--all crops removed	3,600	
Red clover continuously--all crops turned under	9,600	
Alfalfa continuously--all crops removed	10,400	
Grass sod, clipped--nothing removed	10,000	

* Unpublished data of M.F. Miller, Missouri Agricultural Experiment Station.

The provision of liberal supplies of soluble plant nutrients for profitable cereal production demands tillage and the breaking down of organic matter. The organic matter to be broken down should be provided by sod crops, particularly legumes, used regularly in the rotation. Permanent legume sods are effective agents, as this study testifies, in building up the organic matter on soil containing ample minerals--particularly when the crops are not removed. Continuous red clover sod with no crop removal increased the organic-matter content by a total of 9,600 pounds in 17 years, or an average of 564 pounds a year. In similar soil in another plot nearby that was given 2 1/2 tons of clover annually as a green manure under fallow; the annual gain in organic matter amounted to 571 pounds a year (see fig. 3).

New Awareness and New Responsibility

American citizens are becoming conscious of the fact that loss of fertility and the depletion of organic matter in the soil are partly responsible for the menace of erosion. The first step in remedying this situation is to restore fertility by the use of lime and fertilizer. The second step is to put some lands permanently into sod crops--legumes wherever possible, and the better grasses--and to use sod more regularly in rotations on tillable cropped lands. The conservation and use of such farm wastes as crop residues and manures should be included as the third step.

If these practices are recommended as proper soil management by all agricultural agencies, their adoption by individual farmers will become so common that the rate of soil depletion will be lessened. The need for long-time investments in materials that build up the soil in organic matter and fertility should be recognized in granting credit to farmers. Both owners and tenants must accept responsibility for soil conservation and work for it cooperatively. Unearned increment, the great wealth producer of the past, should be recognized as largely responsible for the mining of soil fertility and the burning up of soil organic matter until it has reached such a low level that this source of wealth has an extremely uncertain outlook in the future. The heritage of soil fertility and organic matter that we are handing on to the next generation is not large enough to be used lavishly. Careful conservation and thrifty management will be imperative if it is to yield even a moderate income.

[Source: U.S. Dept. of Agric., *Soils and Men, Yearbook of Agriculture 1938,* pp. 347-360.]