Why Do Farmers Plow?

By Wm. A. Albrecht

Department of Soils, University of Missouri, Columbia, Missouri

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THAT is "an easy question to answer" for the farmers who know how to plow and who "like to plow." They are legion who "get pleasure out of seeing the soil turn turtle," and who will tell you that they plow to improve their crops in quantity and in quality. To fly into the face of the testimony which is the observation of the myriads of tillers of the soil during the ages past, and to deny that there is any scientific basis for this practice, even if it is not known by the farmers, will demand strong and sound evidence.

Without doubt, we have been doing too much plowing, but there is a background of birthright and history for it. North European origin and ancestry, so common in the United States, bring plowing into the foreground as a tillage habit to aerate and warm the heavily textured soils of that climatic region. Farming demanded plowing, and one doesn't make a living without plowing on a farm that is of clay loam or clay texture, and under liberal and regular rainfall. Areas of older agriculture have survived because of heavy soils. Agriculture on sandy soils has been fleeting. Farmers from these older agricultural sections couldn't conceive of farming without plowing. To them, as to the majority of us, the plow has always been the symbol of agriculture.

Plowing without understanding its functions in relation to the soil and the soil fertility, however, now demonstrates that we have done too much plowing—and much unnecessary plowing. There is the inclination in this confession to condemn the very practice itself. Because too much alcohol, strychnine, or opium taken indiscriminately is deadly, shall these stimulants and pain relievers be denied to the physician? We have been too prone to treat all soils, regardless of texture and structure, to the same frequency of plowing. We are just now examining this, at least from the viewpoint of economy.

[1] The first of two articles on the controversial subject, "Do Farmers Plow Too Much?"

Results of Excessive Plowing

During the importation of the plowing idea and the application of the practice in the United States, our ancestry did not recognize their transition to soils that are mainly silt loams, that demand less plowing than European clay loams. They failed to appreciate the connection plowing might have with their movement from regions where the rainfall comes regularly in small showers to those where a large share of the rains are torrential. This failure was more serious in our westward trek to central United States, where the relative torrential nature increases as total rainfall diminishes. This shift from maritime to continental climate was not appreciated until much plowing under torrential downpours put erosion of almost catastrophic magnitude over our most productive areas.

Our ancestors—and we, like them—failed to recognize also that in moving some 700 or more miles southward, one is going toward increasing continentality with its higher and more fluctuating temperatures. Here is the biological aspect of the rapid rate with which the reserve organic matter in the soil has been burned out. This was the basis of the high crop yields enjoyed by the

pioneer for his much plowing. These yields were purchased at tremendous soil fertility costs, and this almost explosive exhaustion of the soil organic matter in our brief history has left the soil less receptive to the heavier rainfall, has encouraged greater run-off, and has brought with it the damaging erosion. Excessive tillage by plow and otherwise has not yet brought us to appreciate that it has also exhausted from the cultivated soils the very plant nutrients that now prohibit nature from quickly growing the vegetation that would cover her nakedness and reduce the erosion hazard.

Yes, we have plowed too much, as our hindsight forcefully tells us. But surely our foresight is better than to allow refusal to plow in the future.

Plowing Puts "Life" Into Soil Factory

Plowing does aerate the soil, as any soil microbiologist will testify. As a consequence of the change of atmosphere in the soil and because of the stirring by the mold-board plow, there is new "life." The soil is a factory in which much energy is expended. It is transforming many substances, oxidizing or burning tons of carbon to carbon dioxide, sulfur to sulfur dioxide, ammonia to nitrate, and other similar combustions. These important facts are disregarded as part of the soil's contribution to production of crops by him who would not plow.

When a 40-acre corn field under maximum growing activity in July is burning to form carbon dioxide the carbon equivalent of that used in running a steam engine of 40 horsepower, can any one deny the necessity of air for such a performance? Surely no one will close the draft and destroy such producing power by refusing to plow.

Air in the soil is not wholly a matter of the shifting water table, as soil science of the vintage of 1910 suggests. Water tables are located at extreme depths. This has been revealed by the numerous studies encouraging soil conservation because it is a practice in water conservation. These depth figures are so large as to be ample evidence that fluctuations of the water tables, even over wide range so far down in the soil profile, could mean nothing in the way of atmospheric air exchange with that in the surface soil.

Then, too, water can move up and down in the soil without moving as a whole water table. It can move without necessarily exchanging air within the soil for that in the atmosphere above it, much as water in the lower half of a bottle can exchange place with the air above it as the bottle is inverted, but yet remains tightly stoppered. Just as atmospheric air plays no role in this exchange of places by water and air in the bottle, just so can water move in the soil and air can move in the opposite direction, without atmospheric air entering.

Then, too, oxidations can occur in the soil in the absence of atmosphere. Chemical compounds of oxygen in the soil give up this element to supply it for various functions. It serves to burn substances in the soil just as saltpeter mixed with charcoal burns the mixture with a speed explosive enough to be gunpowder. Atmospheric burning of charcoal is too slow to make it serve as explosive.

The burning business in the soil by means of oxygen from the air or from chemical combustions serving in microbial respiration must go on if the plant nutrients tied up in combination with carbon are to be released for repeated use by other plants of succeeding generations. Were this performance not proceeding in the soil, life on the globe would soon become extinct. The soil's producing power would soon be expended. All of its chemical nutrients for sustenance of life, or its soil fertility, would be in combination in its own products of growth above the soil. As a result, the soil could offer nothing and no growth could occur. These fires of oxidation, because of microbial

life and activities within the soil, undo these growth products and let the elements make the cycle of growth, death, and decay again. The plow is a means of giving extra draft to hasten this cycle. Shall we prohibit this cycle by refusing to plow?

That plowing improves the efficiency of the soil, not only for oxidation of carbon but also as a nitrogen oxidizing factory to deliver this latter element in the form of available nitrates, is known to those familiar with the more recent developments in soil science. The soil's supply of soluble nitrogen increases during the early growing season as the temperature rises. It may rise to a very high point in fallow soil, or may be consumed by vegetation. It may be leached out by rainfall. It is low again by fall. It declines with the falling temperature or may be held down by excessive drying.

Some studies of the nitrate supply in the soil under corn during the growing season in three adjoining plots, one unplowed, one plowed, and one plowed and cultivated, tell forcefully that plowing provides a larger supply of soluble nitrogen as nitrates, Fig. 1. These were the results also in the absence of the crop and of weeds. Cultivating the soil three times, as corn is commonly handled, provides extra nitrate nitrogen via the soil as the producer of this plant nutrient. Crop yields follow in order of the level of these nitrate supplies. The crop depends on the rate of delivery of the soil fertility.

The farmer may not know that these higher levels of nitrate are the more direct causes of his improved crop yield associated with his making the "soil turn turtle." He plows ahead of the corn planting in order to get a better corn crop. His inability to point out the underlying scientific channels through which the effects of plowing are transmitted to the crop does not put the plow into bad repute in his sight. Surely, the hundreds of corn producers will not suddenly discard so ancient an implement merely because they cannot call to their help this scientific evidence when someone concludes for them that the plow is the cause of increased erosion and other devastation that is so easily associated with it.

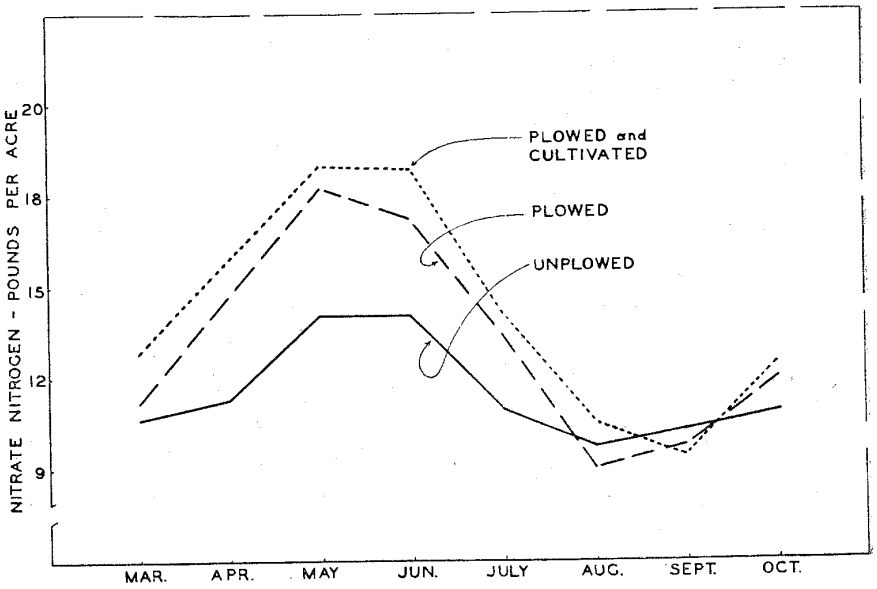

Fig. 1. Nitrate nitrogen under corn during the growing season as influenced by plowing and cultivation.

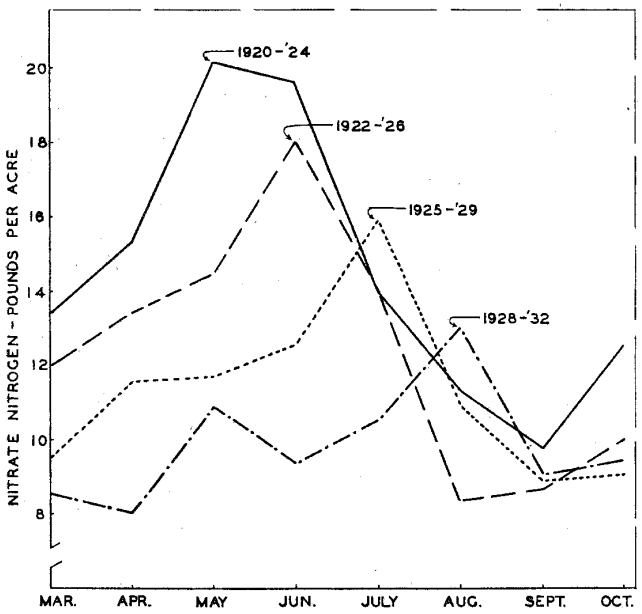

Fig. 2. Nitrate nitrogen levels in soil during succeeding five-year averages for the growing season to show declining supplies with maxima coming successively later in the season.

Plowing and cropping a soil year after year bring with them declining crop yields. For these one might readily pounce upon the plow as the culprit in the case. But one must not forget that cropping includes one crop above the soil as complex vegetation and another one within the soil as simpler biochemical products in microbial operations, Fig. 2. Soil plowed out of sod and put to crops such as corn or wheat, continuously, soon runs to bare land. Shall we blame the plow as it turns under trash and crop residues to make the field look clean? To the uninformed, this would seem to be evidence that "backfires into the argument that plowing produces a better environment for plant roots". The declining crop yields, which we have been trying so desperately to bolster up by imported crop substitutes or by new creations of the plant breeder, have other causes than merely the plowing operation. They cannot be explained away by the simple beliefs that "the explosive separation of the soil mass wrecks all capillary connections temporarily"; and that "the organic matter sandwiched in further extends the period of sterility of the soil due to dryness." Such deductions are much outmoded when they still pin all explanation on the movements of soil water.

Sterility of the soil is not always a matter of desiccation. Much as liquor has come and gone in our many discussions and legislations to eventually find its limited place in human life and let us move on toward a better understanding of nutrition as basic to our national well-being, so the water factor in plant existence has now been accepted as one under nature's control in quantity. Our attention has gone to plant nutrition as the managerial factor, where with little fertility addition we can do much for the plant, even to its water needs. As Mark Twain would have it, water in the soil goes back to the weather about which there is much talk but about which little is done. The factor of soil fertility, or of the nutrition of the plant, is one about which we can do something to give us more and better crops for the weather we have. Crops are as they eat, not as they drink. Fighting the weather is less helpful than fixing the fertility of the soil. Crops are not declining or failing because plowing is drying out the soil.

The forces that push plowed land into bare are not the moldboard plow and the horses or tractor with it; they are the continued removal of soil fertility with little return. They are the gradual exhaustion of the stores of fer-

tility in a soil that must first feed the crop of bacteria within before these life forms can leave something for the crop above. Continued and excessive cropping, along with the product removal, reduce the output of the nutrients left over in soluble form by microbial activity. The microbes merely rework what is given them.

The nitrates, or the available forms of nitrogen, are brought down to a very low level in the soil in June by the wheat crop just before its harvest, Fig. 3. Early plowing in July for the next crop starts their accumulation in the soil again and the curve begins to rise. In the stubble soil the nitrates stay low. But when this stubble is plowed in August, this soil-stirring operation starts the nitrate supply upward. Delay in plowing until September lets the growing weeds reduce the nitrate supply in the soil even below that possible in exhaustion by the wheat crop. Here is a reason based on nutritional evidence that explains why late plowing for wheat makes it a poor crop, even when weeds are turned under as a green manure crop. For wheat, plowing in July makes a better crop, but the same operation in September makes a poorer one. Can we then blame the plow when the same performance in turning the soil is both good and bad for the crop, all within the short time of three months?

The microbial crop comes in for the explanation. The microbes must be fed first. They eat at the first table, the wheat at the second. Early plowing puts under little organic matter. It compels the bacteria to oxidize the humus of the soil that has already been worked over to the point where it has a narrow nutritive ratio, or a small amount of carbon as compared with its nitrogen. When bacteria get their energy, they burn much of the carbon and leave the soluble nitrogen to accumulate in the form of nitrates as nourishment for the wheat, to its better growth.

Late plowing that turns under weeds represents a case of feeding the bacteria with a diet of excessive carbon and of deficient nitrogen. The weeds that grew in the stubble after the wheat had taken most of the nitrogen couldn't be nitrogen-rich. They were carbon-rich or woody. Turned under, this exces-

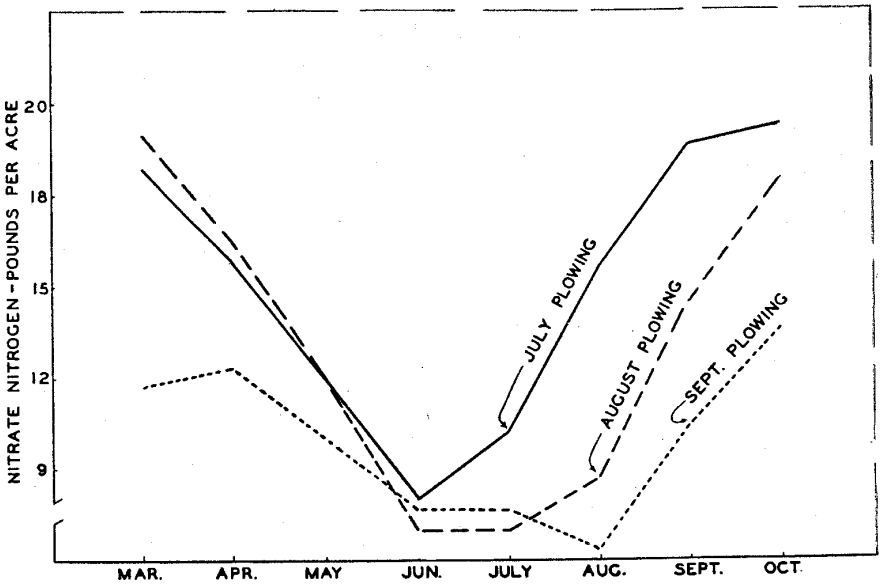

Fig. 3. Nitrate nitrogen levels in the soil under wheat reflect amounts and time of rise related to time of plowing.

sive supply of carbon as energy material compels the microbes to use the soil nitrogen to balance their nutritional needs. They put this soluble nitrogen into complex, insoluble combinations resulting from weed decay. The wheat crop following finds little nitrate in the soil. It starves when in competition for such with the microbial life in the soil.

Under such circumstances, plowing may be given the blame by those who have never understood the bacteria in the soil. But certainly it isn't the plow. It is the deficient supply of soil fertility that is too low to make weeds that can contain much in the way of nutrients from the soil and must, therefore, be made from air and water coming from above the soil. Nutrients from that source can serve to make only woodiness. The fertility is also too low to balance a woody or carbonaceous green manure as the main part of the microbial diet, and to leave anything in addition as nourishment for the wheat crop.

There are other scientific bases for plowing beside the aeration of the soil for the combustion or decomposition encouraged thereby as means of liberating plant nutrients within the soil. Many other phases of microbial life contribute to support the plow as an important agricultural implement. At various agricultural experiment stations, other scientists than microbiologists have given thought to the effects of incorporating organic matter into the soil by the plow and other methods. Basic soil information in connection with the "debacle in which our American soils have drifted" has been established by other men of science who man our various stations. They include those concerned with soil fertility, plant nutrition, soil mineralogy, colloid chemistry, animal physiology, soil, and other aspects of science not even considered as closely connected with soils at so recent a date as 1910. All these can support the farmer in his art of plowing and can give a scientific answer, even if he can't to the question "Why plow?"

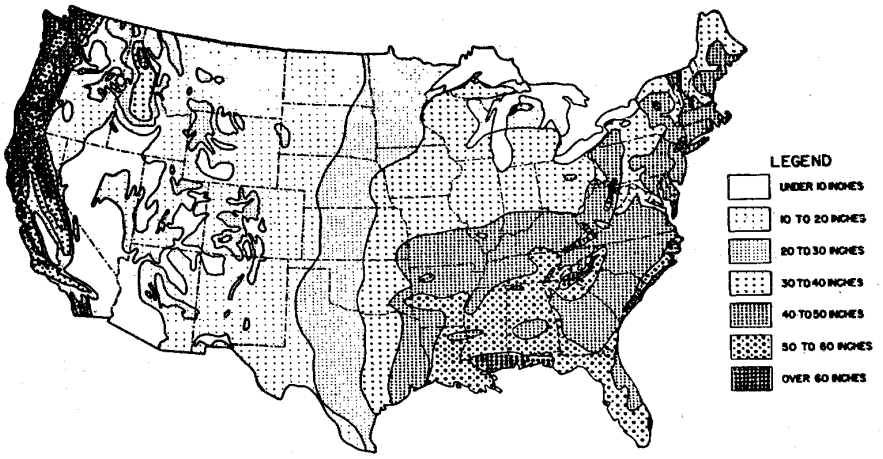

Fig. 1. High rainfall of eastern United States helps vegetation in exhausting the fertility of the soil to the forest level. Lower rainfall of western United States allows minerals to accumulate in the soil. The hundredth meridian marks the approximate balance between these soil-developing forces.

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THIS question comes to the fore now because of recent economic disturbances. When natural power in the form of concentrated sunshine collected on the farm and released locally through horses was replaced by machinery using imported liquid power collected in the ages past and stored in the great depths of the earth, the war's disruption of the far-flung distribution of fuels and oils and its deletion of our sources of rubber were not anticipated. These disturbances, both in terms of mechanics and economics, have led some to believe that high costs of plowing would be best relieved if plowing were discarded altogether as a farm practice. This belief is reinforced by successes under reduced plowing in some areas.

In the face of such a rising belief, the practice of plowing deserves a review of both its vices and its virtues. It deserves more searching thought than attention merely to those aspects that are psychological and economic. It deserves more than tabulation of its values, leisurely and short-sightedly considered. Productivity and plowing had many interactions and interrelations for the welfare of humans long before psychology and agricultural economics obtained academic classification as disciplinary mental activities, or a place as controlling forces in national policies. Production and plowing will, in all probability, still be basic when impending international changes bring many of us back to a much closer rela-

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tion to the soil than we now believe we have.

We need to plow less on some soils. We need to plow more and deeper on others. We need to learn that the differences in degree of soil development according to climatic differences are factors in determining how important the plow is. The farmers in Ohio haven't invested so much in clod-breaking machinery without provocation. The "one-way" land preparer of Kansas is not so successful purely because of its unusual mechanical design. The soil physical conditions, premised on chemical aspects controlling them, have some role in these differences between the forest-bearing soils and those of the prairie-grass growing areas.

There is need to call out against excessive plowing if it occurs, but it is well to note whether it is the advent of the plow or the exit of the soil fertility that needs correction in improved soil conservation thinking. Certainly soil conservation is more than simple mechanics, simple physics, and simple psychology. It calls for some real friends of the land who will try to understand the soil and crop production therefrom in their fundamental connections, to say nothing of the tillage of the soil in all of its ramifications, even into psychology for all of us so dependent in the final analysis on the productivity of the land.

Fortunately, the plow is merely a tool in this whole matter under discussion. The concern about the practice of plowing is one that brings into question the judgment of him who is using the tool, and the purposes he has for it in relation to the soil as a national as well as an individual asset. One cannot condemn the rifle or the pistol as tools because these are now being used in war, when they can render so many more desirable services. Nor would we condemn the mechanics of the automobile when in its human destruction the fault is not one of the machine but rather one of "the nut that holds the wheel." Our knowledge about plowing and our understanding of soils and not the combination of simple moldboard, share, and beam, as handiworks of the engineer, are on trial.

Have you ever thought that plowing may be different according as the soils, the vegetation, and even the animals are different? A few wild turkeys and a few squirrels were the population

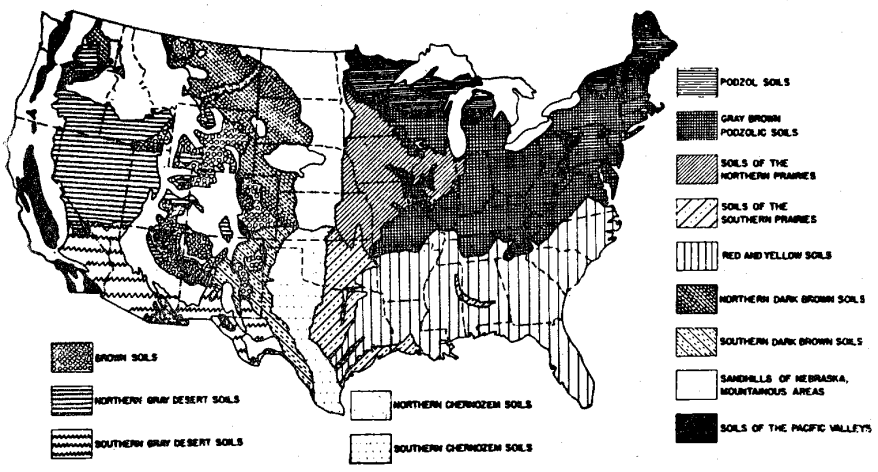

Fig. 2. Different amounts of rainfall make different soils. Different soils make different crops. The fertility supply and its accessibility in the soil are more significant in determining the crops than the amount of water or the temperature. Plant food more than climate determines the plant array. (Marbut's soil map.)

limit in the forest for the Puritans Those same soils, cleared of the forest and cultivated were soon abandoned as agricultural land by the pioneers who were willing to face the hazardous movement westward. All of these facts have not commonly been related to the low rate, and low total, of nutrient delivery by those soils of the lime, the phosphorus, the nitrogen, and other chemical elements needed to make nourishing vegetation for the building of healthy animal and human bodies. Soils that had come down to the low fertility delivery represented by the forest level of vegetation before man plowed them are offering so little for animal body-building that the plow must stir them and every possible help is needed to encourage rapid release of the essential mineral nutrients from the meager stock of organic matter within them. Woody vegetation, according to different acclimated tree or shrub species, and a woody composition of any plant species, including farm crops, are characteristic of "the underprivileged vegetation," on such soils unless they are plowed and stirred to increase the rate of decomposition within the soil of residues of plant generations gone before, or are treated by fertility uplifters in chemical fertilizers and other manures.

But on the prairies, where lesser rainfalls have not developed the soil into what is old age, or more maturity, so far as leaching experiences and nutrient losses are concerned, the vegetation is richer in protein. It is also more concentrated in minerals that contribute to bone-building in animal bodies. The soil itself and not the plowing of it determines these conditions. In going from more rainfall to less rainfall or from eastern to western Kansas, for example, the protein concentration in the wheat goes up. We call it "hard wheat" because, as we commonly say, it grows in regions of lower rainfall. More properly it is "hard wheat" because it is grown on those soils that have more nutritional minerals for the micro plants within, and for the macro plants above them. These mineral supplies are producing not only protein-

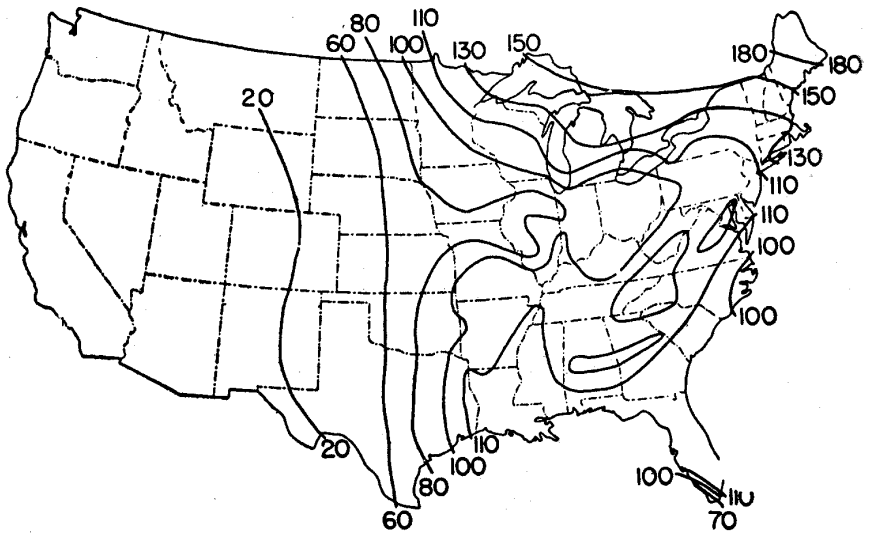

Fig. 3. Larger land bodies and greater distances from seashore modify the effects of the rainfall in making soil. The balance of precipitation against evaporation from free water surface (100) explains why the central states are a part of the western prairies with their soils less leached of their fertility. (Map by Transeau.)

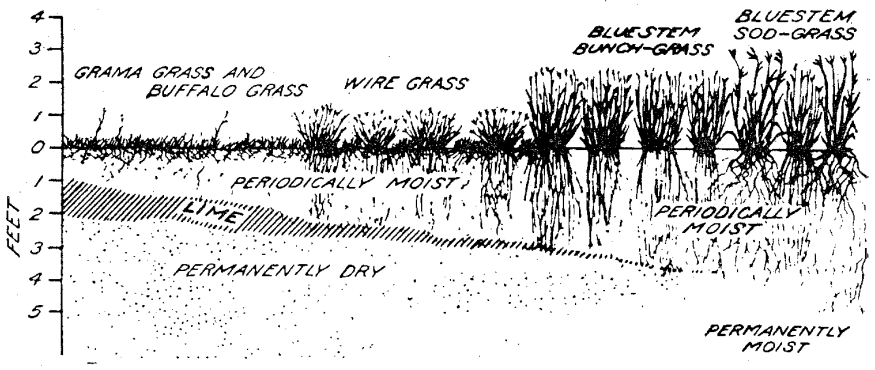

Fig. 4. Increasing soil fertility, particularly calcium, within reach of the plant roots in going from eastern to western Kansas is responsible for the increasing protein content of wheat in going that same direction. (Sketch by Schantz.)

rich forages in legumes like alfalfa, but also protein-rich grain in non-legumes like wheat. Such soils have lime and other minerals nearer their surface where plants can get them to make vegetation rich in calcium, encouraging nitrogen fixation, protein production, and other mineral contributions, all to support animals more effectively than is possible by plants, mainly of fuel value on the highly developed forest soils. We surely cannot subscribe to the belief that all "principles valid for the forest are valid for the fields," when the soils differ as widely as they do under forest and under prairie.

Mineral provisioning of the plants by the soils is now more clearly understood. The ideas coming from the soil mineralogists, the colloid chemists, the plant physiologists and other fundamentals of natural laws are helping us to visualize the processes whereby plant nutrition is brought about and what plowing does for it. It was once believed that plant nutrients were coming from the soil minerals in true solution and were caught up as the plant was taking in and passing on this solution as a water stream to maintain transpiration from the leaves. Studies in plant physiology have recently given us the concept that the nutrient ions move according to physico-chemical laws dealing with the kinds and concentrations of the nutrients on the clay; with the different nutrient ions within the roots in terms of concentration, absorption, and the elaboration into the plant compounds; and with a root membrane interposed between the clay colloid of the soil and the complex colloid within the root.

Plowing has been much confused with water movements from the soil through the plant possibly more by imagination than by actual demonstration. Water moving into the root follows its laws of ionic and molecular behaviors. These are quite different from those of capillary movements given by the high water-table experiments of Professor King. These laws seem to suggest that there is little travel by water as a liquid and that the plant has little to do in the way of control. The concept of the plant as the channel by which soil forces holding the water are balanced against air conditions dissipating it seems to be logical when we remember that plant stubbles and such dead plant parts transpire water from the soil. Plowing has not been connected with the newer concept that nutrient movement from the soil to the plant may be occurring independently of these Gulliverian wanderings of soil water.

Plant nutrient ions like calcium, magnesium, potassium, and others are held on the finer clay part of the soil in an adsorbed form against loss therefrom

by water. They are, however, exchangeable by other ions, particularly hydrogen as an especially active one. That hydrogen is the main item, which the plant exchanges to the clay for what ions the clay offers in trade as plant nourishment, is now fairly well understood as the mechanism of plant feeding. This occurs through a most intimate contact by plant roots with the soil particles. Plant roots extend themselves through the soil to get their nourishment by means of this trading process. Little credence can be placed in the belief common only a decade ago, that the soil gives nutrients to the plant. The performance fits more nearly into the country boy's understanding of how we get milk from cows, when he said, "our cows don't give milk, we take it from them."

The effects by the root as a nutrient gatherer may extend through a distance from the root of but a few layers of clay particles right next to the root. This is limited probably to distances in millimeters, certainly not to such extensive distances as centimeters. The root systems' effects as nutrition are also commensurate with the total root surfaces. Accordingly, then, the densely matted collection of roots under bluegrass takes more total nutrients from the colloidal part of the soil than does the sparsely rooted crop, like soybeans.

Each root leaves the soil in its immediate zone of activity exhausted to a very low level. The advent of the root has opened channels by which nutrients could go out and energy compounds come in. In fact, it brings about, either directly or indirectly through its own decay and bacterial activities, a reduction of the compounds of the soil about its area of penetration. This reduction may be indicated by a color change from the customary reddish to the drab gray soil, much like we know it to be brought about by water-logging. One might expect roots of the next crop to follow successively in these old exhausted root channels, if the soil were not stirred. Plowing serves as a mixing agent to redistribute this reduced clay amongst those clay portions that were not so nearly exhausted of their supplies of nutrients.

That plowing is more essential for this purpose than we commonly believe is indicated by the increasing report of observations of deficiency symptoms suggesting plant diseases of some crops, such as cereals and some of the legumes in such a close sequence as to reduce the amount of plowing. Soils put under fall-pastured barley as nurse

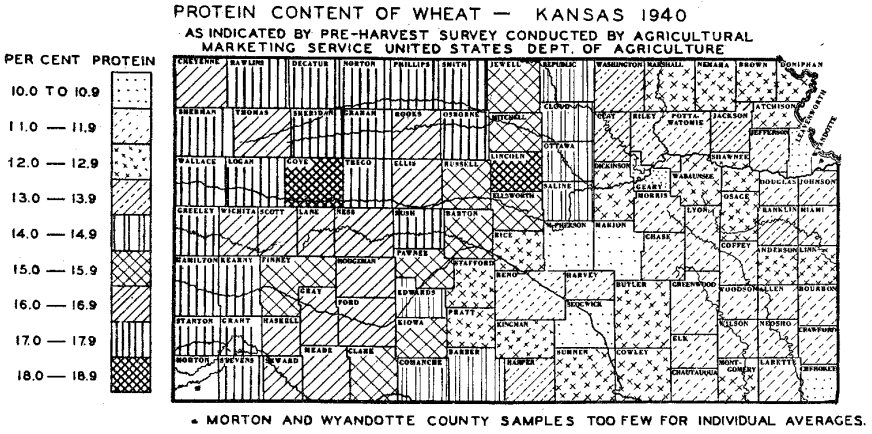

Fig. 5. The increase in protein content of wheat, from 10 to 18%, in going from eastern to western Kansas follows the increasing supply of fertility in the upper soil horizon. Hard wheats are determined by the soil more than by weather or rainfall.

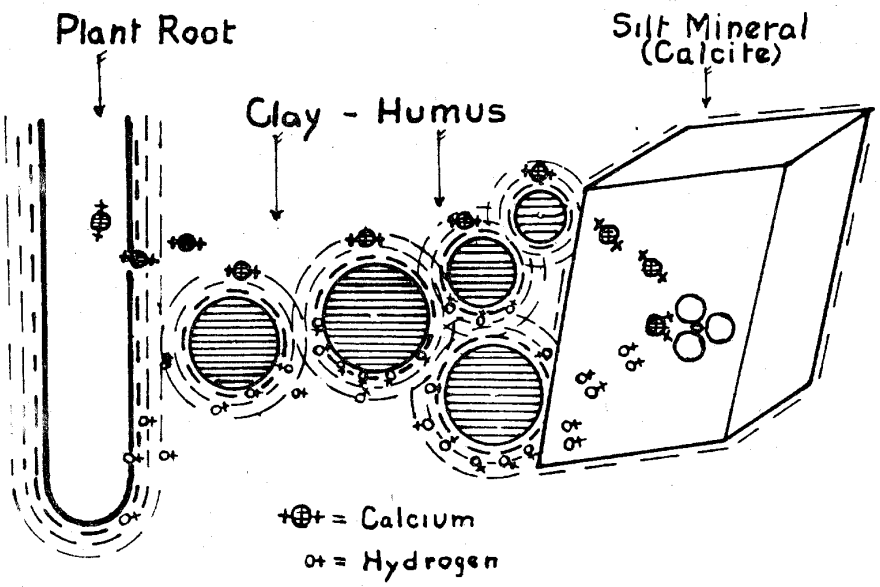

Fig. 6. Nutrients, like calcium, move from the mineral to the colloidal clay and humus, and from there to the plant roots (right to left). Hydrogen, or acidity, traded by the root for nutrients, goes in the opposite direction to break down the mineral crystals like limestone and to put the calcium nutrient into availability for the plant.

crop for summer-pastured lespedeza to be disced and to go to barley again in another annual cycle with only this limited tillage are showing nutrient deficiencies that are not prevalent under plowing. Plowing serves to shuffle the exhausted soil surface into contact with other surfaces not so depleted. It is apparently significant for the crop nutrition that such soils be plowed between even two successive crops. It may be true that the farmer cannot appreciate the colloid chemistry and low levels of nutrients in the soil concerned with the crop disease symptoms, but he does appreciate the improvement in the crops after he plows. He is justified in developing a reverence for the plow much as you and I develop a reverence for the dining-room or the kitchen, if reverence of that type is the limit in our thinking.

Plowing serves for nutritional improvement of the crop by mixing the different clay areas in the soil. Dr. Graham's researches at the University of Missouri have recently pointed out that plowing may be instrumental for better plant nourishment because it shifts the connection between the surfaces of the clay and surfaces of the silt, or the larger mineral particles of the soil not commonly considered so active as exchange performers. He demonstrated that the nutrient ions in the mineral silt moved to the clay in the absence of plants, and that plants picked them from there to their better growth advantage than from the minerals directly. Periodic shuffling of the clay in contact with the surfaces of the silt particle, or after the clay has become saturated during the period of contact for a few months, is the means of keeping more of the clay loaded with nutrients to be passed on to the plant root. Plowing is the means whereby enough clay in the soil picks up enough nutrients from the silt, and other original reserve supplies of fertility, in active forms and in amounts sufficient to give us the quality and the quantity of crops we need to produce.

This then is the picture of plant

nutrition as we visualize nutrient elements coming from the soil. It is a chemical performance within the soil to which plowing and other similar mechanical measures contribute speed. The nutrient ions adsorbed on the clay move into the root in exchange for hydrogen ions coming from the plant root to take their place on the clay. The clay on becoming more extensively saturated with hydrogen ions—the active producers of soil acidity—passes them on to the silt and to other mineral soil particles as the means of weathering the nutrients out of these original rock forms. Thus, by means of plowing, the clay is rapidly reloaded with a stock of nutrients, or is buffered against what we have been viewing as dangerous, excessive acidity, but which is in reality dangerous soil fertility exhaustion.

As has been demonstrated by Dr. Carl E. Ferguson at the University of Missouri, this exhaustion of the clay's nutrient supply would occur in but a few crops were it not for the silt. It is through these steps, namely, rock to clay, clay to plant, that the nutrients pass. It is in the reverse direction, root to clay, and clay to mineral, that the weathering effects by the plants in the form of hydrogen as acidity travel for soil depletion of its mineral nutrient supply. Plowing increases both of these reciprocal movements of the chemical elements, and thereby facilitates what concerns most of us, namely, food production.

Plow Is Not Exploiter

Plowing merely hastens many of the same processes that are occurring more slowly when "the land is resting." When land must be allowed to rest in order to boost its productivity back to economic levels again, this is merely proof that the fertility supply on the clay is exhausted so nearly to completion and the mineral reserve of fertility has fallen so low that the interactions between the clay and the minerals are too slow to move enough nutrients on to the clay surface to provide sufficiently for the roots during the growing season. Plowing isn't the cause of the depletion of the fertility supply. Depletion occurs because of the fertility removed within the crop hauled off. The plow is not the exploiter; rather, it is the farmer. The plow is merely the tool that facilitates his exploitation at a faster rate and over more acres than before the plow was given him. The plow has helped him to feed many of us too far removed from the land to appreciate its exploitation.

Some of our plains have been exploited to such an extent that even the plow can't substitute for the time needed to restock the clay from the mineral reserve. These soil processes are too slow in rate, and too limited in amounts of fertility mobilized thereby, to finish, for example, one wheat crop in June and to germinate to a good start another crop by the succeeding October, even with the help of plowing. This is the case of a plot on Sanborn Field in Missouri, where wheat has been seeded annually without fertility restoration since 1888. This plot is now taking an annual rest on its own accord after it produces one crop. It has become a yielder only in alternate years. This is because the soil fertility delivery processes that are moving nutrients from the soil minerals to the clay and from there to the roots in exchange for hydrogen going in the opposite direction are too slow to give ample supplies unless an extra year elapses. Fertility and not water are concerned. Surely, such a biennial performance with regularity over almost 25 years is not a case in which "the soil simply takes time out from its business of growing things until the restoration of its normal water supply." Food more than water is involved.

Here is a suggestion that any accusation of the plow as a responsible agent for soil deterioration is a misplaced and unfair condemnation. Such accusation would still seem just, even if by the best of science we should lay bare every

Fig. 7. Underprivileged animals go down with rickets when compelled to live on vegetation produced by soils exhausted of their fertility.

principle of only physics that plowing of soil involves. Even if we should dispel the belief that "the exact physical effects that follow the operation of the plow have never been subjected to scientific scrutiny," the plow might still be listed for its exit as an implement. Plant production is more than applied physics and particular mechanics. It is a matter of delivery of the required plant nutrients. The soil processes providing nourishment within the soil are slowing down because of soil fertility exhaustion more than through bad mechanics premised on "what we learned in elementary physics in high school."

Shifts in the kinds of nurse crops and in the kinds of legumes in order that we might accept substitute crops are very striking evidence of soil exhausted of its nutrient reserves. Not only is the slowing down reflected in grain crops by their alternation between a crop and a crop failure, older apple trees become alternate-bearers. Older cows pastured on and fed products from many soils of declining fertility go on similar biennial schedules in reproduction. Surely the plow isn't to be blamed for what happens in the subsoil under the apple trees or for nutritional irregularities on permanent sod pastures that come to light in terms of breeding troubles in cattle.

If we are to bring the plow into this picture of "the debacle into which our American soils have drifted," the case could not be rested on the contention that while the farmer's "reputation for smoothness and neatness of the plowed field was developing, no thought was given to the possible connection between smoothness of the land surface and exclusion of the rainwater from the soil." Antediluvian ideas about water in the soil, about the wet subsoils under freshly incorporated green manure interpreted as interrupted capillary rise rather than "sweat" from the respiring and decaying organic matter—to say nothing of many other ideas almost equally hoary—don't convict the plow except for those unfamiliar with more recent soil science. Plowing and crop production are more than water problems. No one will deny that even these are serious enough. Declining soil supplies of fertility are making the water problem worse as we allow the plants to starve for nutrients while they are wasting their water transpiration and carrying on within themselves little or no construction of the organic, nutritional complexes they are intended to synthesize. Water will be the lesser of the soil troubles when we understand nutrition, and when we feed the plant so that what water we have will be used most effectively for crop production.

Starving plants do more damage than merely that of wasting water. They invite attacks by bacteria and fungi to cause much that is regularly called "plant disease." Starving plants are symptoms of soils that are no longer stable in their desirable structural conditions known as granulation. Their surfaces are hammered flat with the first dash of rain and are moved off in deflocculated condition as erosion in the balance of the rain. To the eye and mind that are observing soil fertility, numerous other plant and soil symptoms are clearly visible. For such

an observer the real debacle about agriculture is that we continue to exploit our soil resources without giving the slightest thought to the fact that these unrecognized and unappreciated chemical changes within the soil are basic to erosion, to disturbed agricultural economics, to distorted national economy, and to a disturbed national health, as draftee rejection figures reveal.

This larger problem is aggravated by the plow, but also by any tool, either mechanical or psychological, that encourages and permits continued exploitation of the fertility of the soil in the same manner as we mine and consume many other resources. The land is the basis for our existence by way of the food it provides for use. The mining performance of it has brought us to where it is difficult to change and to shift into using the soil only as a site for soil fertility "turnover" by putting in about as much of plant nutrients as we take out in crops.

This shift to letting land rest, to putting out the land to grow cover, to encouraging organic matter restoration, to purchasing fertilizers as a definite program of returning almost the ash equivalent of the crop removal demands more than that the farmer quit plowing. This shift to squeezing out the charges assessed against an unearned increment, and to going back to an acre value of the soil as a producer after deducting costs of fertility maintenance, labor, and investment carriage even at the low rate acceptable to the man of the soil whose hope for security is still pinned to the land, is a change that calls for more than invention of a scapegoat in the form of the plow.

The understanding of the processes in the soil as a producer of our foods has become a challenge to an increasing number of people. Friends of the land are multiplying so that with a knowledge about and deep concern for the soil, they will not long leave unanswered the question, Why Plow?

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