DECLINING SOIL FERTILITY . . .
Its National and International Implications

An Address by Dr. William A. Albrecht

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at the

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DECLINING SOIL FERTILITY—ITS NATIONAL AND INTERNATIONAL IMPLICATIONS

DR. WILLIAM A. ALBRECHT (Chairman of the Department of Soils, University of Missouri): Mr. President, Senators and Representatives, other Distinguished Guests, Members of the Organization, Ladies and Gentlemen: I find myself suffering from the emotion which goes with the feeling that a good number of you have heard my Soil story before. Yet there is encouragement in learning that some of you are patient enough to bear with me a second time.

Nevertheless, the story we try to tell about soil is one which needs repetition, even in our own minds. We have been telling it for so many years that it might appear to become monotonous. But it dare not become so because, if we are going to get anything done about it, it must be told and retold. So, while this is an occasion which has so many familiar faces, I feel I am not among strangers but among colleagues as reinforcements in a great cause.

It is not our intention to discuss the practices of liming, but to reach back into the principles which underlie the need for liming the soil and to give, first, the national soil picture, then, second, the international one. So I come tonight to talk to you about the soil and to remind you of a rather pessimistic aspect, namely, our declining soil fertility. We have been mining our soil instead of managing it. We are just now beginning to think about the management of our soil from a national standpoint. I hope we may begin to look at the soil also from an international viewpoint.

In order to simplify the presentation, it will not be divided into three parts, as all Gaul was, but into four. I should like to make the following four points, or at least have four divisions of the subject.

First, we, as individuals, are more closely connected with the soil than we might believe, even though we live on the paved streets, where the Indians said "they ought to put a town here because nothing will grow here."

In the second place, let us understand why limestone is used, where it is used, and why it is used where it is used.

In the third place, we shall present some experimental evidence of the declining soil fertility and the implications, of that decline, in our feed and our food values. Then, in the fourth place, we can make the international implications which go back to food and, by those implications, go back to the soil.

EXHAUSTING THE FERTILITY LESSENS CROP PRODUCTION, WEAKENS THE SOIL BODY, AND INCREASES ITS EROSION

If you will remind yourselves about our soils, you will notice, of course, that we have become conscious of the fact that soils are eroding. We have not thought of the reason why soils erode; we have merely taken the common way of calling in the mechanics to help us stop the running water. But water always runs downhill; it always has. We have not thought enough about why the soil is eroding, even though there has been no change in the rate of rainfall in the last few hundreds of years. However, there has been a change in the soil. We have attributed soil erosion to the rainfall, and have been fighting the speed of the running water, instead of watching the changes in the soil.

Your attention is called to the fact that in our humid region with its high rainfall we have a surface soil and a subsoil. The surface soil does not erode very seriously, but when running water cuts into the subsoil, that horizon erodes away quickly. The surface soil is well granulated; (it takes in the water; it holds the water) but the subsoil is not. In our humid region we have had rain going down through the soil and removing the fertility; we have had the roots pulling the fertility upward and saving for themselves what they could, retaining it in that surface soil. As long as there is this fertility strength in that surface soil, then, we have almost no erosion, but when we have a surface soil depleted like the subsoil which has little or no producing power in it, then we have erosion.

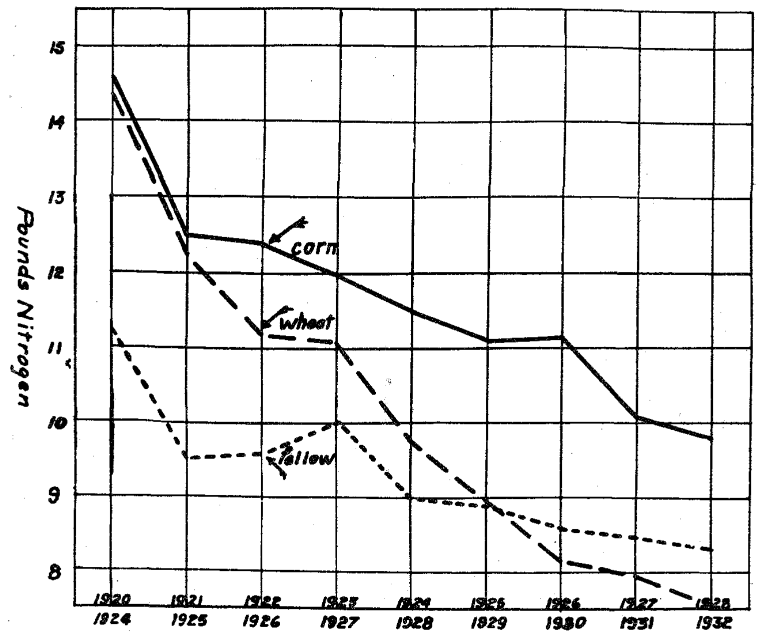
We submit for your consideration the fact that erosion has come because we have weakened the soil body. In turn, the body of the soil has been weakened because we have taken out of it what we call the fertility, namely, those elements which help that soil to grow cover for itself.

Nature is not a nudist by choice; she is a nudist because we have taken from her the means by which she grows cover. When we have a fertile soil, and one which is deep, we do not need to worry about erosion; it will grow cover before the rain can carry the soil away. If we have a soil which is loaded with calcium, we have it flocculated. If we have it loaded with calcium, it will grow proteinaceous substances for humus, which gives the colloidal binding power; which hold the granules together; which stand up under the hammering rain; and which the rains will not stir up into a slush and wash off.

If we can have a deep fertile soil, we will not have any serious erosion. It is the fertility, or strength of that soil we need to recognize, namely, strength in terms of its producing power as well as strength to resist erosion. We have not realized that the plants growing in shallow surface soils are struggling for their food. But when we shatter the subsoil and put some potential nutrition down into it, then the roots are going down deep. So the problem of erosion is not only one of putting fertility into the soil, but it is one of making the fertile soil also deeper. When we talk about this matter of soil erosion, let's remind ourselves that as we weaken the body of the soil through cropping or other uses so do we make it erosive. Consequently, the problem of preventing erosion is one of putting strength back into that body to make that soil strong, so that it protects itself.

Just as an illustration of how the body of the soil has been changing in its physiology, we have an illustration in the case of nitrate production in the soils, especially during the growing season from March on through October. Most people do not know that the soil goes into action as the temperature gets warmer in the spring, and things are happening within the soil to make the crops grow. It is the common belief that the warm sun shines on the plants and that makes the plants grow. On the contrary, as the sun shines on the soil, the soil begins to make its nutrients available by microbial activity, and the plants begin to be nourished. The plants, then being fed, go into action, but not because the weather is warmer for the plants alone.

We have an illustration from some research at Missouri, for the five years 1920 to 1924, where annually there was a rise in the nitrate supply of the soil to reach its peak in May, or just at the time when we plant corn. Then, as the corn took those nitrates out they disappeared or the supply was lowered. Under these continuous croppings to corn, for the five years from 1922 to 1926, the maximum came later by one month and it did not mount as high. In the next five-year period, chosen for three years later from 1925 to 1929, the maximum came still another month later and was at a much lower figure. In the next five-year period which was chosen the maximum was still later and lower.



The levels of soluble nitrogen in the soil during the growing season (pounds per acre) go down under cropping or fallow cultivation at a surprising rate, to wear out many a soil in a single generation.

From such results one can see how we plow out a sod to start cropping the soil and, with time, the producing power for nitrate in that soil goes down. Finally that soil is so low that there is not the usual seasonal delivery of nitrate as fertility and corn production drops. It is important that we realize that the soil is a dynamic performance, which is seasonally tuned to nourish those crops. The crops are not seasonally tuned merely because of temperature and the rainfall coming along in rising amounts with the season. We have been looking at the temperature so commonly as the control when it is only indirectly in control by way of what it does in the soil to nourish the crop.

Some studies were carried on at the Missouri Experiment Station from 1918 to 1932, a total of about fifteen years, to see what happens to a soil in its total nitrogen supply when we do nothing but cultivate it or when we turn under a legume crop. Where we did nothing during the fifteen years, the nitrogen dropped from about 2,200 to about 1,900 pounds as a total per plowed acre. Where we put back the equivalent of 2½ tons of red clover as a legume, we built up the soil. Here is evidence that we can manage, much as we may propose to do, if we understand just what we are trying to do with the soil.

We are appealing for a better understanding of the dynamics, of the physiology, of this soil just as in medicine the doctor must understand more about the physiology of the human body. We have not thought that the strength of the soil body is much like what we call the "constitution" of the human body. We can think of the constitution of the soil just like you think of the constitution of an individual. I do not know how you define it, but I define "the constitution of an individual" as the capacity to stand up in spite of the doctor rather than as a result of him. It is the capacity for you to go to the hospital and take the treatments or operations and still come out alive. That is what the constitution is in the body. we can think much the same way of the constitution of a soil.

Two plots of soil at Columbia, Missouri, have been in continuous corn since 1888. In one of our late rainy springs we were waiting for it to be dry enough to plow them. One of those plots has been in corn, with nothing done to it except being given the the privilege of growing corn. The other has had the same cropping treatment plus the addition of six tons of manure annually. On a Friday afternoon when the soil was about dry enough to be plowed the plots were photographed. They were plowed on the following Saturday morning; on Sunday morning a rain came along; and on Monday morning they were photographed again. So there was demonstrated the weak body of the soil which ran together with the rain when never manured, and the strong, granular body of the soil which stood up in spite of the rain where manure was used regularly. But the strength of that soil body was not a matter of its having been plowed; not a matter of its having been mechanically set up; but a matter of the inherent fertility through manuring which granulated it and made it maintain its strength in granular form against the dashing rain. We may well think, then, about the soil body, its weakness and its strength, just like you do about the human body.

AGRICULTURAL CREATION STARTS WITH THE SOIL

The soil is the starting point of the assembly line of food production, and of the creation of all which we call agriculture. If you will look up the analyses of the human body, you will find it is 95 percent combustible. But if you look at what comes from the soil, it is not four elements like the carbon, hydrogen, oxygen and nitrogen coming from the air and water to be combustible, but it is a long list of them. At the head of the list in the largest percentage is calcium, namely 1½ percent of our body. The next is phosphorous, making up 1 percent, and those two together make up the bones. Then we come to potassium as the third on the list in order of amounts.

But if you look at the chemical analyses of the plant, the highest in amount is the potassium, because the potassium is associated with the carbohydrate production, namely the conversion of the air and the water, by sunshine power, into carbohydrates or fuel foods. But then the calcium comes next and the phosphorus next, because they are associated with the conversion of those carbohydrates into proteins. Protein production is the major problem of food production. By means of air, water and sunshine power the plant makes fuel food values; but by means of the long list of fertility elements coming from the soil the plant converts those fuel values over into protein and other body-building values. Protein is the only thing which can multiply itself; it is the only thing which can grow or can transmit life. There is where the fertility of the soil comes in, namely in the perpetuation of life, in growth, and in reproduction. Protein synthesis is not dependent wholly on sunshine power. The plant must first make its energy compounds; then, by its own physiological processes, for which several on the list of soil fertility elements are required as tools for construction, it consumes those fuel values and converts parts of them into growth values.

These concepts are significant since as long as we take bulk as our only criterion for agricultural production, we can bring in new crops, which spend themselves in making vegetative bulk but not in making proteins. Whenever you talk about the protein crops, you are talking about those crops which are said to be "hard to grow", meaning that something must be added to most soils to nourish them or to keep them growing even to make bulk. When we talk about the soil, we need to think about its services in the reproduction of the species. We think about their growth, but we do not want to think about planting crops for the sake of bulk only, because mere bulk of food does not necessarily nourish. One can grow pine trees as a means of making bulk but even a squirrel will not try to live in a pine forest, because he can't.

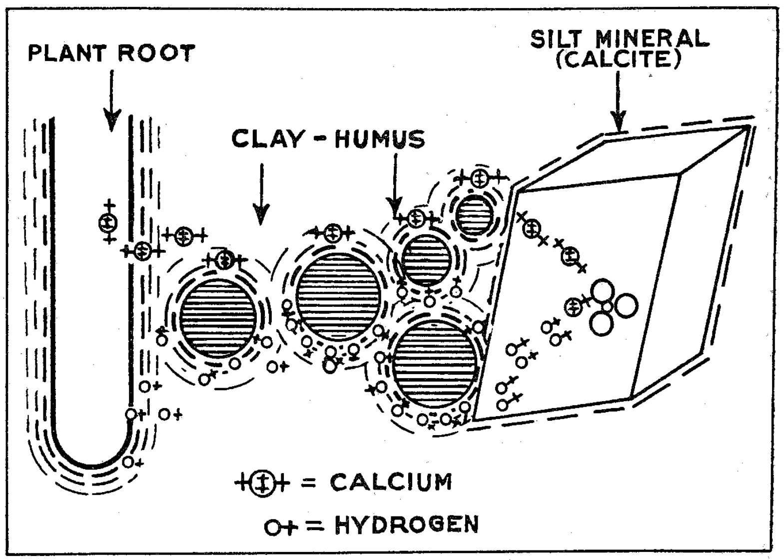
When we talk about using lime and phosphorus, we have been considering those two in agriculture to make more bulk of crops. We have not thought about the far more important crops, namely, the human crops as dependent on the soil for more than calories. We have not thought when we look at a newborn baby in x-ray that the facial structure has well-formed bones. Then, if we find a youngster at the age of six, whose mother says "He is having trouble growing his teeth; he never eats correctly; he does not do this or he does not do that"; we do not realize his poor health responsible when he already has his teeth impacted, and his jawbones are too short for anything else. We have not thought that nature has absorbed or failed to grow a great deal of his facial structure as early as at six years and that he has not been building bones like they were even in the newborn. Unfortunately, we do not have x-rays to help us look into the faces of all our boys and girls and to help us think about calcium and phosphorus in terms of nutrition. We have merely been talking about lime and phosphates to make bigger crops and about growing something to sell. If we can find the next fellow who will buy we seem to be satisfied.

It is high time that all folks begin thinking that agriculture is food creation, and that the assembly line of that process starts in the soil. The soil is the point where you trip off Nature and set her going. The soil is a far better taking-off point and control than any other place in the assembly line. When we reach in to correct or to cure anywhere else along that line we are not so effective. Postmortems never contribute very much to the good of the fellow who gives the information on that occasion.

LIMESTONE IS A FERTILIZER FOR HIGHLY WEATHERED SOILS DEFICIENT IN CALCIUM (AND MAGNESIUM)

For about twenty-five years we have been recommending and using lime on our soils, while thinking about limestone as ammunition to fight soil acidity. (Seemingly it must be the Irish in us, that makes it necessary to have a fight before we can get a crowd to think about any particular matter in question.) Time and information have come for us to forget that we are not putting limestone as a carbonate on the soil to fight acidity. We are putting it on as a calcium fertilizer. Calcium must be present very early in the life of every plant, as can be demonstrated very easily. The plant will not grow very well if we give it mainly potassium or magnesium salts as fertilizers. But put on a little calcium, even as a chloride form, or put it on as an acetate, either form of which makes the soil more acid, and yet the introduction of the calcium makes the plants start growing earlier. Many of our soils are too low in this essential element, calcium, which helps the plant get started more quickly in taking other nutrient elements out of the soil. We are not appreciative enough of the fact that the calcium is important in that performance by the roots. Calcium is a "synergistic" agent. It is a major control of the mechanism which sets up the roots so that the other nutrients move into the plant instead of in the reverse direction, namely, from the plant back into the soil.

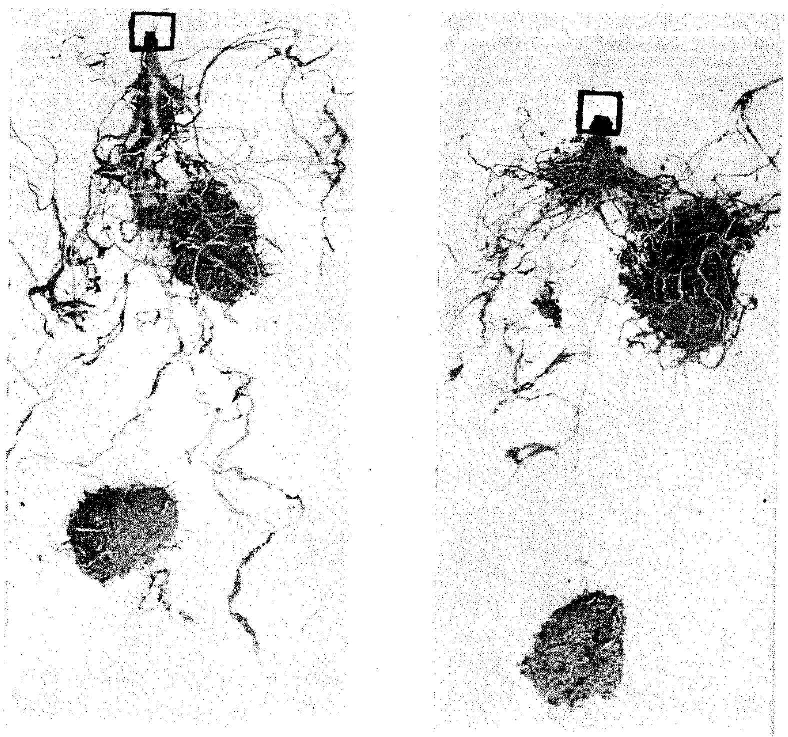
Few people have thought that plants might be giving their life substances back to the soil; but we have had experimental proof that nitrogen, or phosphorus or potassium may be going back to the soil while the plant is growing. The final crop may be lower in total in these respects than the planted seed. The clay of the soil is either giving or taking. Unless the clay carries plenty of calcium, the clay may be **taking** rather than **giving** other nutrients to the plant root. There must be considerable calcium in the soil before the plant can get it. When the plant has its roots in the clay which is highly saturated, or if there is much clay of less degree of saturation by calcium, then the plant is well fed in this respect. The clay is the absorber and exchanger of nutrients. Plants trade acid or hydrogen for them. Acid clays are active clays. If we put such a clay between the plant root and any mineral, including limestone, the clay as an acid is more effective in weathering the mineral than is the root itself. So the clay, as a go-between, that is, between the mineral and the root, is a



The assembly line of agricultural production starts with the breakdown of the silt mineral to pass its nutrients (calcium) through the humus and clay colloids to the plant roots. The roots in turn pass hydrogen or acidity in the opposite direction as a means of getting their nutrient supplies from those minerals Soil acidity is naturally beneficial.

very helpful agent in making the root more active for its own nutrition. The clay is the jobber or the agent taking up and giving out the nutrients. As a consequence, in plant nutrition we fertilize the soil and then the plant. It is in these respects that the clay of the soil is very important.

According to the map of limestone consumption in the United States up to this date, this calcium fertilizer is used in the regions where the soils have considerable clay and enough high rainfall to have made them acid. While that rainfall was making those soils acid or was putting the hydrogen in, it was also taking out the fertility. Consequently, limestone is used on soils that are deficient not only in calcium but also in other nutrient elements. For many years we have used gadgets to measure that hydrogen coming into the soil and being taken up by the clay, but we did not have gadgets to measure the calcium and the other fertility going out. We were content with our thinking as the result of those gadgets. We said "Soil acidity is bad because, in general,



Plant roots seem to search for and find the centers of fertility in the soil as shown by the number of large roots in these clumps of phosphated manure that was plowed under. Only a very fine root is needed to deliver the nutrients from the manure clump to the plant. Photo by courtesy of Dr. A. R. Midgley, Vermont Agricultural Experiment Station.

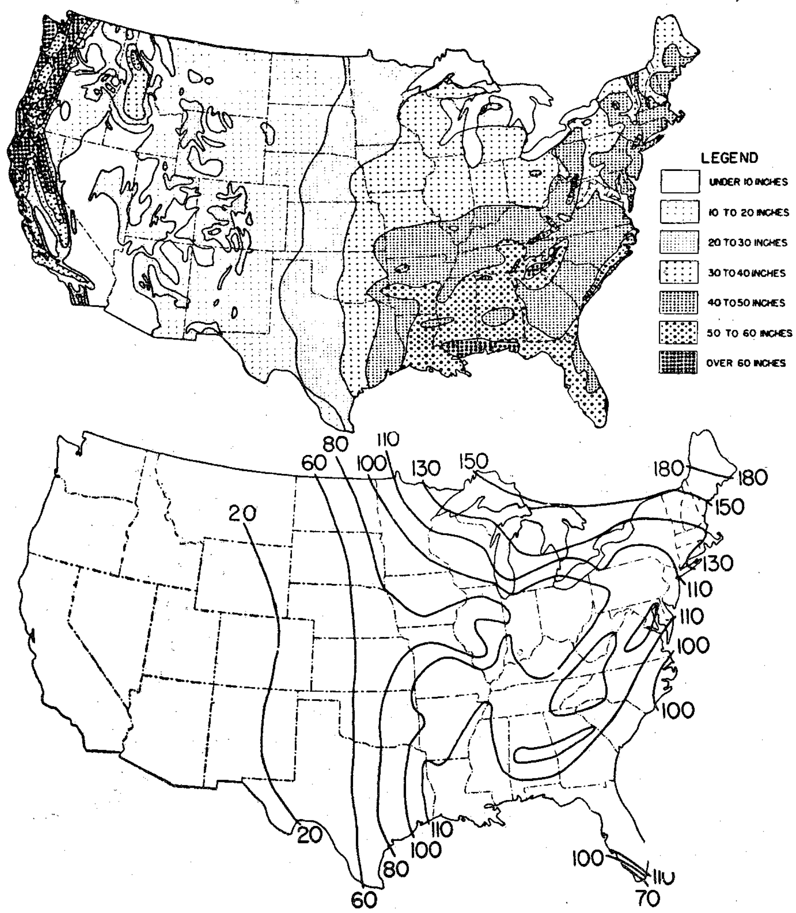
as the soil is more acid, the crops fail"; when we should have said that as the soil is more acid, more fertility has gone out. It is not the detriment of the acid coming in, but it is the detriment of the fertility going out, that should have caught our concern.

The South has been using no limestone because those soils are not so acid. Yet the South needs calcium and has been using much of it unwittingly. The folks there have been using mixed fertilizers, of which superphosphate is the major ingredient, and every bit of superphosphate contains two or three times as much calcium as phosphate. We have been crediting the phosphate when we should have been crediting the calcium with part of that fertilizer benefit. It would be far cheaper if the South would start using limestone and would begin to think about having a mineral reserve of calcium in the soil. Highly weathered soils of the East, acid in the North or not acid in the South, need limestone for better crops.

THE CLIMATIC PATTERN OUTLINES THE PATTERN OF SOIL FERTILITY, AND OF THE NEEDS FOR LIMESTONE

The soil is a temporary rest stop of the rock on its way to solution and to the sea. While that rock is making that temporary rest stop as soil, the plant reaches in and snatches up some of the things it needs for growth. In some places those essentials have moved on so completely that crop production is difficult. The rainfall is pushing the rock onward, hence the rainfall pattern of the United States is also the major part of the soil pattern. Disregarding the West Coast and starting with zero rainfall just east of the Coast Range, we come eastward with better soil as we move from the West to the central portion of the United States. Most people say, "Well, more rain makes more crops." We ought to say that more rain makes more and better soil to feed the crops more effectively. It is more than water that makes crops. As the belts of annual rainfall increase from 0 to 10, 10 to 20, 20 to 30, and 30 to 40 inches in coming eastward, we have increasing soil construction until we reach the middle of the United States. In the West, lime is left in the soil. In the East, the lime and other fertility have gone out under the high rainfall to the point where soil destruction takes place. The rainfall map is the starting point for our recognizing that we have an East and a West in the United States and for our having a North and a South in the eastern half. It is the soil which gives us those differentiations of the country into regions.

Soil is the result of rainfall, of course, but also of the evaporation coupled with it. If you will divide the annual rainfall in inches by the evaporation in inches from a free water surface (which means that the rainfall evaporates and does not go through), you have only about 20 percent as much rainfall as evaporation in the western United States. The figures increase on coming eastward with the increasing rainfall. We have the temperature effects making the Cornbelt for us, because the rainfalls there come in the summer, when the winds blow from the West and the evaporation is high because of both high temperatures and high winds. As a consequence the line of rainfall that is only 80 percent of the evaporation gives a curve swinging eastward to where we have more rainfall but also more evaporation. In the Cornbelt we have the rainfall to break down the rock to make clay and to load the clay with fertility. We have the water evaporating to leave on the clay, and in an available form, what elements it broke out of the rock, instead of leaching them down through the soil and to the ocean. According to these natural forces, the



By superimposing the map of rainfall (upper photo) on that of the ratio of the rainfall to the evaporation one obtains the soil map of the United States. (See illustration on page 28.)

Creator made the Cornbelt for us by means of that rainfall-evaporation ratio, with the high rainfall to hammer the rock down to make the clay and to load the clay with nutrients instead of washing them off and putting excessive amounts of hydrogen or acid on the clay.

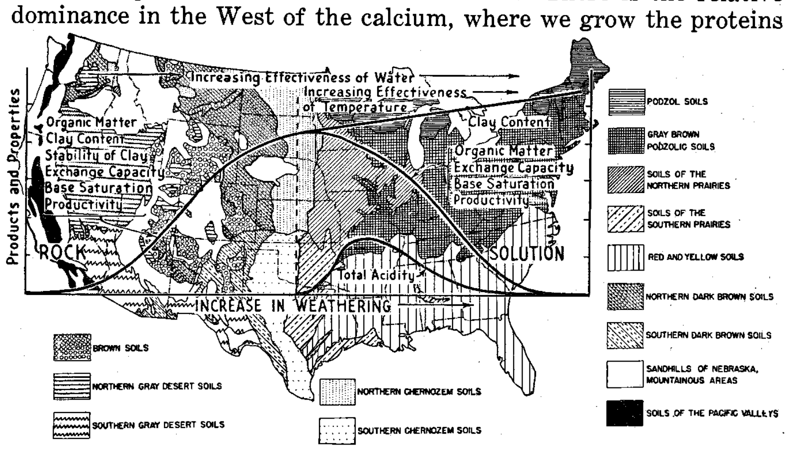
If we take the rainfall map of the United States and that of the ratios of rainfall to evaporation, and then if we superimpose one upon the other, we get the soil map of the United States. The line in about the middle of the U. S. running North and South gives us the lime-carrying soils to the West and the lime-deficient soils to the East. It divides us into an East and a West.

It is the soil that also divides the East into a North and a South, not because of color lines in the people but because of a color line in the soil which makes a different kind of clay in the South from that in the soils of the North. In the northern half we have a clay which is still a silicate. It is a tremendously able absorbing agent and is tremendously high in its exchange capacity. It has a tremendous power to hold acidity, and it has a corresponding capacity to hold fertility, if we will put it back there where the acidity has replaced it. We put limestone on that acid soil. In reality, that acid is beneficial, because it serves to break down the limestone and to load that soil with available calcium which is first and foremost in the clay-root dynamics of moving the nutrients from the clay into the plant.

We have been making some big steps forward in our national program with calcium use in this Northeastern region where the soil-plant dynamics necessitate it and where we have learned the basic principles that may guide us extensively. But in the South we have a clay which is approaching its development under tropical conditions. It is red or, as we classify it, lateritic. It does not have the exchange power; it does not hold what we have put on the soil as fertilizers. The materials go through the soil to the ocean. That is the soil in which we need to have a mineral reserve slowly being made available. On the soils of the North we can put the lime or other fertilizers and the soil will hold them.

Because the soils of the South are so different from those of the North there are entirely different philosophies demanded for managing them. Consequently, one cannot go out with a single prescription and apply it universally. One must know his patient if he is going to be a successful doctor. So likewise one must know his soils if he is to prescribe for the good health of agriculture. Prescriptions on a national scale must go back to the basic control of all agriculture which is this soil. These prescriptions call for good answers to many questions. Does that soil have the clay which it needs or which will function in feeding the plants, the animals and us? Does it have reserve minerals which can still be broken down as we find them out in the western United States, where the rainfall has been too low to break them down? If we are to get ourselves in a position to manage the whole business of agriculture properly under wise prescriptions, a capable diagnosis of the functions of the soil supporting it must precede. As we diagnose our soils more according to their functions through fertility and less to their acres we are beginning to see the larger agricultural picture. We are coming to understand why we use limestone on the soil.

So putting the pattern of soil development theoretically, we start with the rock, and with the increase in weathering from western U. S. to eastern U. S. we are building up a soil but with construction only up to a certain limit; then if we increase the forces of weathering, we pull its creative values down. Soil is then under destruction. In that theoretical pattern we first make alkaline soils; then we make excessively calcium soils; then we wash the calcium out and make acid soils. Then, if we raise the temperature along with the rainfall, we make red or lateritic soils. That is the soil pattern across the United States. There is the relative dominance in the West of the calcium, where we grow the proteins



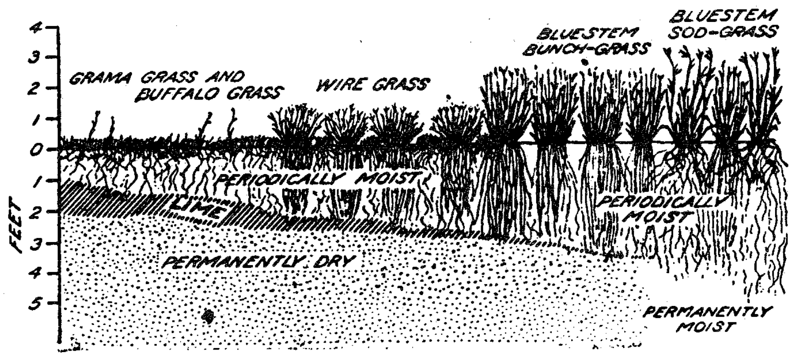
The climatic soil groups of the United States (after Marbut) show that the various soil characters contribute to higher nutritional values in the Mid-Continent. From West to East there is increasing clay content but this means first soil construction in the West (calcareous soils) then soil destruction in the East (calcium-deficient soils) in terms of food quality for man.

and the legumes naturally. In the East, there is the relative dominance of the potassium, which makes the wood or the forests. In the West we have the dominance of the animals which assemble their own protein; in the East we have the animal troubles, because we have them confined, and the declining fertility of the soils gives us breeding problems not yet diagnosed as originating from that source. If we will put the theoretical curve of soil development on the United States, we have a climatic soil pattern and one which, if duplicated anywhere in the world will help us to understand why the agricultural output there is similar to that of the United States. If we will observe any agriculture according to that climatic pattern of the soil, we can tell what we have.

As we come to the central United States from the West, the soil acidity comes in and builds up tremendously in the northern and northeastern region; then if one goes to the South, it goes down. This whole matter of soil acidity is simply the equivalent of a deficiency in fertility. Calcium is the first one of the whole list of fertility elements we need to put back into the depleted soils, acid in the North and not acid in the South to help the plants to help themselves to recover their power to grow and feed us better.

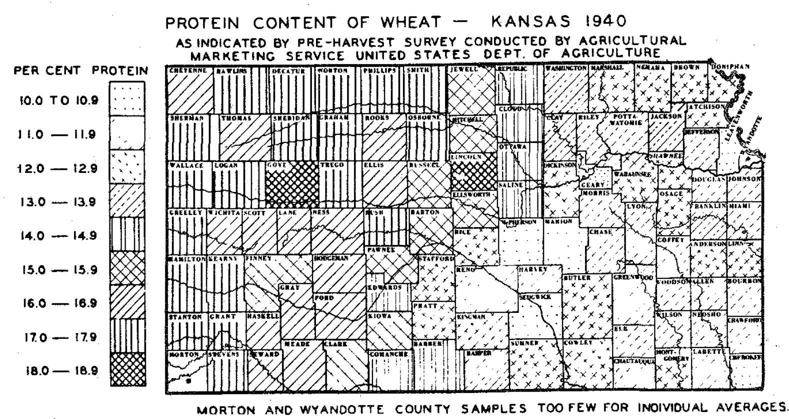
THE FOOD PROBLEM OF MAN AND ANIMALS IS A PROTEIN PROBLEM CALLING FOR LIMED SOILS TO GROW PROTEIN AS WELL AS CARBOHYDRATES IN THE CROP

Lime in the soil is related to the food quality that soil delivers. If you will look at the virgin vegetation of the United States, you will find that the coniferous forests are in the Southeastern and in the Northeastern States, with the hardwoods sandwiched in between them and the Central States. As the soil has been washed out more, forests are the crop. As you go from the middle United States either southeastward or northeastward you go from the grasses to the hardwoods and then to the conifers. In the mountainous West, where theoretically we have not yet made a soil, we also grow coniferous forests. So whenever there is the deficiency of the complete soil, both Nature and we can make only wood. What about the chances for higher life like man or animal under those soil circumstances? We already had, in the virgin vegetation (when this country had 3 million Indians) some very good suggestions as to possible systems of agriculture and guides for our own thinking if we go back to the physiology of the plant for that guidance instead of being concerned only about crop varieties and tonnages of bulk per acre.



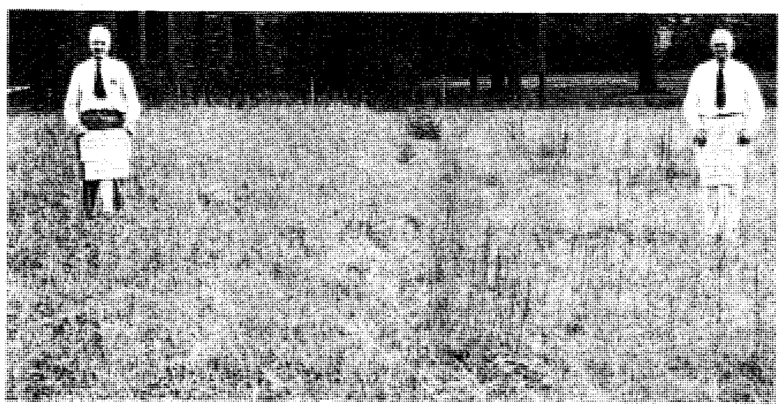
The virgin vegetation across Kansas (with 17 inches of rainfall in the West increasing to 37 in the East) shows more bulk with more rainfall but also more highly weathered soil. The buffalo's choice grass was not the one with most tonnage per acre on leached soils.

If you happen to be an enthusiast about grass, this kind of virgin vegetation also pointed to the soil fertility under it. An old graph of thirty years ago by Professor Schantz, showing the grasses native to Kansas, told us that as we go from its seventeen inches of rainfall at the western edge to thirty-seven inches at the eastern one we have more and more yields per acre of the grassy vegetation. Everybody still believes that more rain means more crops, but we need to ask what quality of the crops? Schantz pointed to the soil for that. He sketched the lime layer in the soil a foot thick and within a foot of the surface in the West, but showed it deeper down in the soil and finally disappearing with



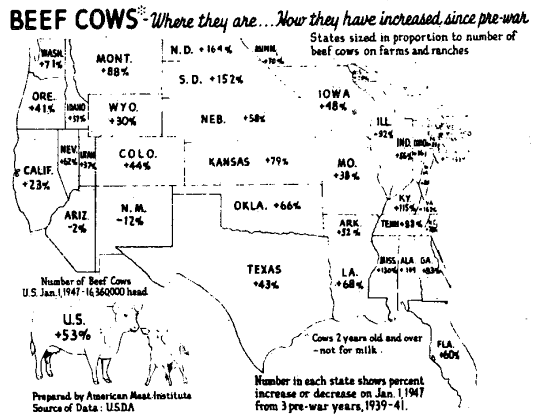
The protein concentration in Kansas wheat decreases from West to East as the rainfall and bulk of virgin crops increase. Highly weathered soils produce lower concentrations of protein.

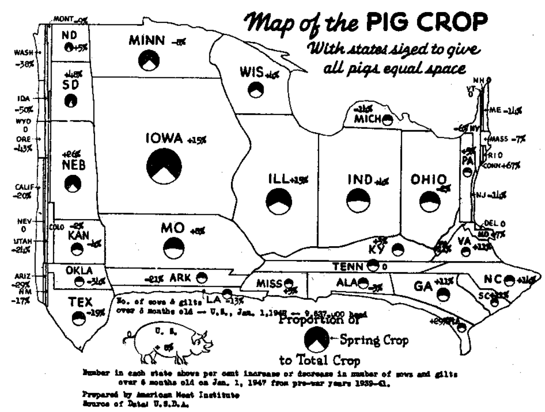
more rainfall on coming eastward. The virgin vegetation suggests why the bison stayed where the lime had not been leached out of the soil and where the other elements of fertility were also left to help the grasses make proteins rather than only fattening foods. The buffalo gave his name to the grass which was more proteinaceous. He did not buy protein supplements. Yet on that grass every little buffalo grew to be a big one, and every big one made a lot of little ones. The buffalo delineated for us the pattern of our wild animals as dependent on the fertility of the soil. The buffalo didn't get his calcium from the mineral feed box. He preferred to stay where it came from the soil via the grass.



Continuous grass (timothy) for sixty years without lime and other fertilizers (right) has now been "Taken" by broom sedge while good timothy starts early and stays late in the season where soil treatments are used (left).

A map by counties of Kansas showing the concentration of the protein in the wheat in 1940 points to the 10 to 11 percent of it, in eastern Kansas. If you take the lower tier of counties and go west across the state the figures go up to 18 percent of protein in the wheat. That range from 10-18 percent of protein in wheat goes back to the differences in the soil for those differences in protein. In order to make protein, the plant must have nitrogen first. But in order to convert that nitrogen into protein it must have a lot of other fertility to go with it. According as we have highly leached or washed-out soils, our crops make starches with many bushels or high yields per acre, and do not make so much protein. Consequently in the South and even in Missouri, just east of Kansas we eat soft wheat. Why? Because we do not have the fertility combination in the soil by which to make the protein.





Beef as high protein concentration on free range is the product on our less weathered soils. Pork and its high fat content under more confinement are the agricultural output on our highly weathered soils.

The food and feed struggle is one for proteins everywhere. It is the proteins that are needed even to supplement the fattening of our animals in the Cornbelt; it is proteins that make hard wheat; it is proteins that make meat. Protein is the major goal in the food struggle. Protein deficiency is the hidden hunger—to my way of thinking—which we all suffer. That hunger goes back to the plants in their same hunger going back to the soil with lime a major deficiency.

If we take a look at the map of the concentrations of our domestic animals, we see that we make beef most extensively in the same soil area where the buffalo made his beef and bone. Beef is a good grade of protein. The beef cow does not take to making fat naturally. She will put on fat only when we confine her inside a fence and stuff her with corn that grows—where starch making is the major crop potentiality. When beef production is located where the plants can make more protein, as the beef cattle concentrations on the soils of the "hard" wheat area testify, we begin to comprehend why Kansas City is now the beef cattle market, with Omaha running a close second, the little town of Springfield, Missouri, increasing its size as a cattle market, and Chicago no longer the major beef cattle market. Protein production as beef has gone westward with the exploitation of our soils from East to West.

Have you ever thought that the mining of our soils has pushed us westward and that we have not gone in that direction just because we want to be nomads? Had you thought about some of our food problems in terms of the exploited soils which we left in our wake as we came west? Had you thought that we are exploiting the Kansas soils now even though the yields of wheat per acre there are going up because it is physiologically simpler for the plant to make a "soft" wheat than to make more proteins along with more yield as bushels? The plant must burn its sugars in order to make proteins. That means that high-protein wheat naturally does not make so many bushels per acre. As we continue to mine the fertility out of our soils we are pushing even "hard" wheat into a smaller and smaller region of our West. This matter of making protein either as beef or as "hard" wheat is a matter of soil fertility. It is not one of sunshine and fresh air only, but sun and fresh air first to make the starch out of which the plant can make the protein, provided the soil fertility is supplied to convert the starch into this food constituent of body-building values.

We make pork or grow the hog in the eastern part of the United States. Because that animal lives only six months, we do not need to carry the responsibility of keeping it well fed very long before we can pass the carcass on to the butcher. Nevertheless, one must grow that pig first before you can fatten it. Our soils that fatten the pigs do not grow them very efficiently. On those soils we have only a 60 percent dairy calf crop and only

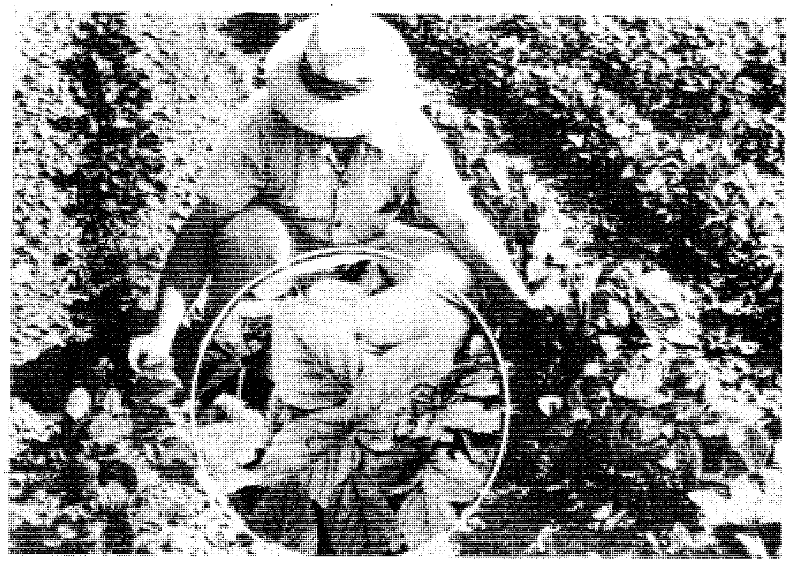
60 percent of the pig crop lives to be marketed. The sow turns the litter of pigs over to us at farrowing time and before we can handle that feeding responsibility for growing them for six months, we are down to 60 percent of the number with which we started. Are we very good animal husbandmen? If the soil gets much poorer, are we not going to be even worse custodians of the lives of our domestic animals?

AS LIME GOES OUT OF SOIL READILY IT LOWERS THE PROTEIN PRODUCTION BY CROPS WHILE THEIR CARBOHYDRATE OUTPUT HOLDS UP

A study of the chemical composition of (a) 38 of our different crops and plants grown on soils only **slightly** weathered in midwestern United States; (b) 31 cases of them grown on the **moderately** developed soils in the central United States; and (c) 21 cases of crops grown on the **highly** weathered soils in the southern United States shows that the calcium, the potash, and the phosphorus together make up 5 percent, as an average, of the dry matter of the first group; 4 percent, roughly, of the second group; and only 2 percent of the third group. The crop's contents of these soil-contributed elements of nutritional value go down very rapidly in percentage, or the combustible part of the plant goes up as the soils are more highly developed or weathered under more rainfall and temperature. In other words, the protein-producing power and the bone-building power dwindle; but the fuel-producing, the energy values or the characteristics we measure by calories, hold up, even on the less fertile soils.

All limestone producers should be interested in the fact that in the proteinaceous crops we have a high ratio of the calcium to either the potash or the phosphorus, namely 6.8 to 1.9. The calcium disappears during weathering and cropping at a greater rate than anything else. Our soils decline relatively more rapidly in calcium fertility than in other nutrient elements, because calcium is one of those elements that gives its place relatively quickly to other elements. That changing ratio of calcium to potassium during weathering of rocks and soils is the basic principle behind this matter of making protein along with carbohydrates or making only bulky carbohydrates.

This principle has been demonstrated experimentally. Soybeans were grown with a constant amount of calcium available in exchangeable form, but with increasing potassium. Increasing the potassium increased the starch and the bulk, until there was an increase in the yield of bulk of the crop which amounted to 25 percent.



Soybeans, once considered an "acid tolerant" legume cannot tolerate starvation. They require soil fertility to make a seed crop. Once considered a "hay and not a seed crop", they have demonstrated what poor feed quality they are as hay if grown on soils not fertile enough to make a good seed crop.

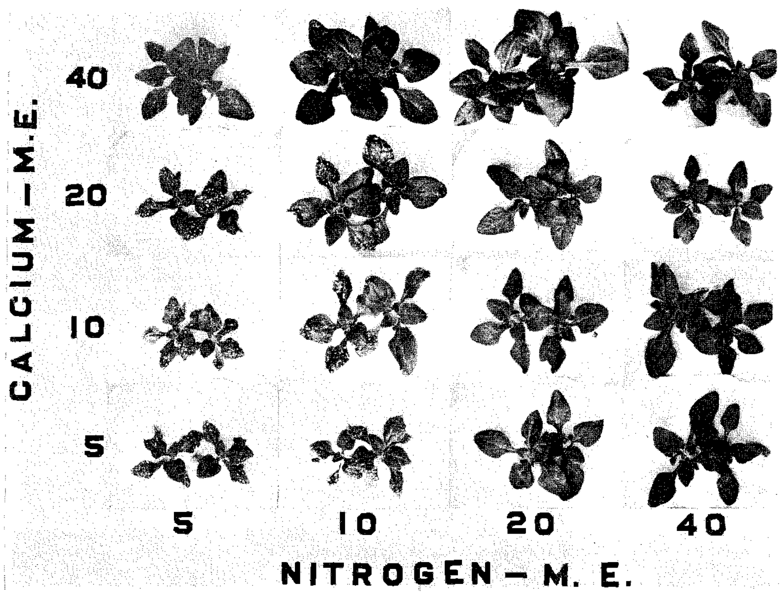
While the average agronomist gets public applause when he makes five blades of grass grow where four grew before, the increase in the bulk of the crop in these experiments gave a decrease in the concentration of nitrogen, which is the index of protein. In going from the small crop to the larger tonnage of hay per acre, the percentage of nitrogen dropped by roughly 25 percent or one-fourth. There was less protein produced per acre in the large crop than in the small one. The concentration of phosphorus in the small crop was .25 of a percent and in the large crop only .14. In the case of calcium, this nutrient element dropped from .74 to .27 percent or was cut to one-third of the concentration by the mere increase in hay yields.

If you can imagine the cow which is going to eat that hay, is she going to be able to spend the extra time eating three mouthfuls instead of one to get her calcium, or is she going to spend normal time eating one mouthful and becoming deficient in calcium—assuming the total bulk is equally digestible? Cows do not belong to the union; they do not ask for portal-to-portal pay. They go to work at daylight and they work until dark, and they can put only about so much hay through themselves per day because they have only a 4-inch cutter bar. Can they suddenly increase their intake by three times? They cannot suddenly become hay bailers because of that declining feed quality. Nor can they make up the difference by trebling their intake. As a consequence of that decline in hay quality with declining soil fertility, the cow's reproducing power goes down and the lower percentages of calf crops result. The output of milk goes down with that declining reproducing power. Do you see the significance of this soil-cow picture connected with the quality instead of the quantity of the feeds and foods we are growing as we continue to mine rather than manage the fertility of our soils?

LIMED SOILS HELP PLANTS TO MAKE PROTEIN FOR THEIR BETTER PROTECTION OF THEMSELVES AGAINST DISEASES AND INSECTS

Had you ever thought that as we go from a virgin soil, with good, healthy plants, to an exhausted soil, we ought to expect sick or insect-infested plants? Had you ever thought that we ought to be talking about improvement of the fertility of the soil as a means of **preventing** plant disease and insects on them? That such are the facts was demonstrated experimentally by merely increasing the amount of clay in a sand planted to soybeans, even though it was an acid-calcium-clay with a pH of 4.4. Merely increasing the clay meant more root contact and more lime in the plant to grow healthier. The difference in that amount of lime through more clay in the mixture made the difference between a fungus attack under little clay and an immunity to the fungus under more clay. This happened when the plants were all in the same greenhouse and exposed to the same infections.

Some experimental work using four but increasing amounts of nitrogen for spinach coupled with four but increasing units of calcium that was duplicated ten times, found the thrips insect moving in to eat the leaves of only those rows of spinach given the lowest two amounts of nitrogen. They did not attack the two other rows given the highest amounts of nitrogen. The replications ten times all demonstrated the attacks on plants growing



More Calcium (horizontal rows from lower to upper) and more calcium (vertical rows left to right) as means of helping the spinach plants synthesize more protein give better protection against the leaf eating thrips insects.

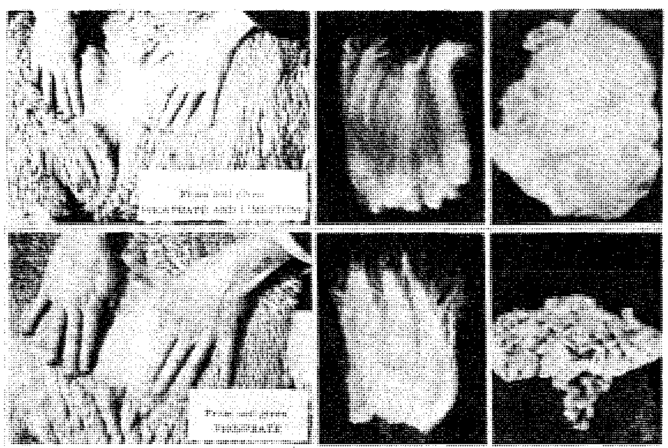
with little nitrogen and the insect absence on the plants given nitrogen more generously. Also, as there was more calcium added with the two lower amounts of nitrogen, there were less thrips in these two plant series. Had you ever thought that by feeding a plant more lime and more nitrogen to help it make more protein you make it immune to attacks by both fungi and bugs? Such facts are suggesting that we might well rearrange the old adage and say "to be well fed is not only to be healthy, but even immune to the attack by fungus diseases and insects, so far as plants are concerned."

Not only insects but our domestic animals discriminate against the crops according to the differences in the fertility of the soils growing them. A cooperating farmer let us demonstrate this on 100 acres of his virgin prairie, where he makes hay every winter. He fertilized four acres at the end of the field, with lime, phosphate and nitrogen, with the idea of improving the virgin prairie as pasture. After taking a careful inventory of the plant species, yields and their chemical composition in the late summer, the entire field was made into hay. He made his usual four haystacks, each consisting of the hay from twenty-five acres. One of these had the hay from the four fertilized acres swept in and mixed through it. In the wintertime he turned his cattle in to the field to consume that hay, only to find that they passed by the first three haystacks in coming from the barn and the water, to consume first this distant stack containing the small amount of hay grown on the fertilized soil.

Hogs selected the grain first in that part of the field where Mr. Long of Warrensburg, Missouri, had once treated the soil to grow alfalfa. In "hogging down" the corn these "dumb brutes" select their feed according to the fertility of the soil growing it.
—Photo by Virgil Burk

The first and the only soil treatments were made in 1936 when his verbal report was made concerning the discriminating choice by the cattle. Each year thereafter the cattle gave the same discriminating demonstrations and photographic records reported them as late as 1943 or the eighth hay crop after the single fertilizer treatment. These effects were demonstrated by 273 head of cattle and for an application of fertilizer on the surface of the soil at no greater rate than a total of 600 pounds per acre.

Some experiments with sheep demonstrated different amounts of growth according as they were fed (a) hay from soil with no treatment, (b) hay from soil with phosphate, and (c) hay from soil with both phosphate and lime. There were seven lambs in each lot, and the growth per lamb per 63 days was eight pounds, fourteen pounds, eighteen pounds, respectively for the different soil treatments of the same variety of hay and when they ate exactly the same amount of hay per head per day. During the next autumn when the sheep were to be mated with the ram, the two groups fed hay from the first two soil treatments given above were not yet sufficiently mature to mate and to give lambs the next year, while the third group was.

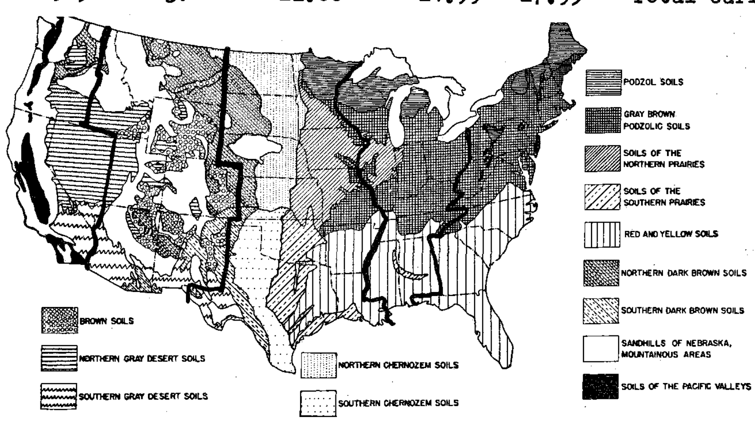


Wool as a product of the body processes of the sheep contained much "yolk", and carded out into fluffy fibers (upper photos left to right) when the sheep was fed on hay grown on soil given phosphate and limestone. It contained little "yolk", could not be carded, and broke into a powdery mass (lower photos left to right) when the sheep was fed on the same kind of hay grown on soil given only phosphate.

Enough hay was left of the second and third soil treatments beyond the needs for the sheep trials to feed some male rabbits used for artificial insemination studies. The hay grown with the phosphate treatment reduced the semen-producing power to where they refused to mate with a doe in oestrus. The males fed the other hay declared their interest in such a doe the moment she was brought into the building housing them. In order to test these demonstrations again the hays and rabbit lots were interchanged. In just three weeks the situation was reversed until those males which had been sexually active were sexually indifferent, and those which had been sexually indifferent were sexually active. It took only three weeks to make that transition.

In dealing with soil fertility in its relation to our domestic animals, we are striking at a vital matter, because it is in the animals' reproducing power that declining soil fertility really is so disastrous. Failing reproduction is causing us to think about the trace elements. A small matter like a deficiency of manganese may cause trouble. Manganese is one of the trace elements which the limestone man ought to remember. When we make a soil neutral, manganese is not going into the crop. Manganese deficiency is going to come on rapidly if we use lime to the point of making the soil neutral.

9.10	8.80	8,38	10.06	11.45	Cavities
6.40	4.30	3.70	4.89	6.10	Fillings
15.50	13.10	12.08	14.95	17.55	Total Caries



The pattern of defective teeth in terms of caries revealed by Navy inductees shows the minimum tooth trouble in the Mid-Continent but increases to the East and West. Its curve is the reverse of the curve of soil development.

In order to make the soil fertility picture a bit more human, attention was turned to the data from the Navy's studies of about 69,000 inductees in 1942. By using the Navy data of the number of cavities, fillings, and other conditions of the teeth of the inductees by the various regions of the country and recalculating these for the various states adjoining on the opposite sides of the line which divides us into an East and a West, there are 8.38 cavities per mouth and 3.7 fillings, or already, at the age of 24, the total caries of 12.08. If we open our mouths, we can tell how poor our soils are. If we go west to the next longitudinal belt of 2 states wide, the figure steps up to a total of 13.10. On the west coast the total figure is 15.50. If we come back again to our 12.08 in the central area and go east, the total figure goes to 14.95 and then to 17.55. Then if you take New England alone, it is 21.

By such data we begin to see the human health pattern, even in just the teeth. What about the bones in your body? The teeth are only an exposed part of your skeleton. What about the rest of your skeleton? You begin to see that we can look into the faces of people and almost tell whether you ought to sell more limestone. It is our opinion that we ought to take the statistics of our different health conditions and make maps of them and then superimpose each on our soil map. Knowing the soil deficiencies then we might well get suggestions or at least raise such questions as "Can it be a phosphorus deficiency? If the soils are neutral, can it be a manganese deficiency? Can it be a boron deficiency?" Because those are the deficiencies which come when our soils are neutral either naturally or because of excessive liming. I believe we ought to begin studying our soils in relation to failing health. From such there might well come the suggestion for a take-off in the prevention of some of our diseases, if not for the cure.

THE INTERNATIONAL SOIL PATTERN SUGGESTS THAT THE SOIL FERTILITY IS BASIC TO OUR INTERNATIONAL PROBLEMS

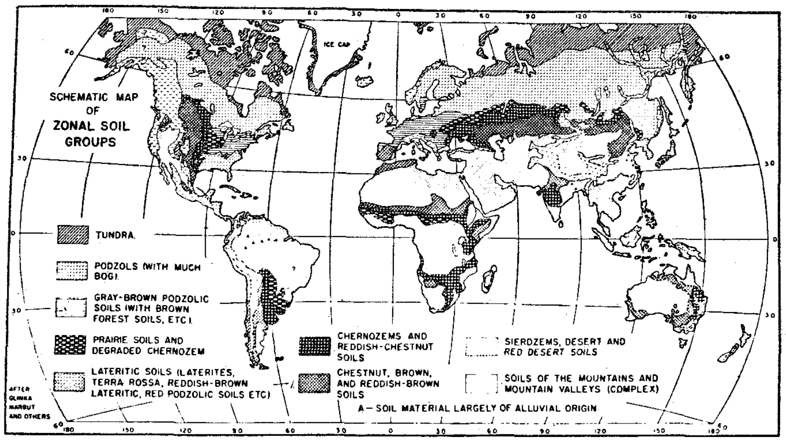
Up to this moment you have seen the national pattern and some of the experimental evidence of the implications of it. Let's look at the international soil map and, having the United States and its producing power before us according to its soils, let's look at the rest of the world to find the areas equally as fortunate. Immediately you turn to Russia to see that the Russians are one of the world powers because they have the same kind of soils as we have with the protein-producing power. They have their cowboys, but they call them Cossacks, those hard-riding, those hard-shooting boys who made the Czar's army, and were not charged any taxes by the Czar. Russia is another area like ours where the "hard" wheat grows; where they had good eyesight and keen trigger fingers about the time Hitler got over near Stalingrad.

Take Mussolini. Where did he go? He headed for North Africa. Because both Hitler and Mussolini in the region too far north of the Mediterranean, along which civilization originally moved on those worn-out soils, had hungry crowds. They put them in the army. So did we, but we preferred to have them lean on shovels instead of guns. We called it WPA, and they called it the army; that is the only difference.

You look at Australia, South Africa, India, to find they have protein-producing soils and as British possessions make Britain also one of the world powers. We may take a look at any part of the world, and see the protein-producing power in the Temperate zones, unless we have altitude to make other zones like it. The limited area of the world which has protein-producing power makes us realize than our increasing population is putting a real high pressure on the soil. We have had good warnings in the books like Mr. Osborn's "Our Plundered Planet" but, somehow or other, we prefer to be complacent about soil fertility shortage and believe that science is going to solve it. A look at the world soil map reminds you that it is not acres; it is not the two dimensions of length and breadth; it is not even the three dimensions of length, breadth, and depth, but it is the four dimensions of length, breadth, and depth, plus the strength of the soil's body which we call the fertility.

So our human health and our human thinking power (because our brains are no better than our bodies) are going to be just as strong as we maintain those forces in the soil which do something more than feed us fuels. While we have been content up to this date with a criterion for agricultive of tonnages and bushels, we need to add a new criterion, namely, the quality of our agricultural product as it serves in nutrition. We need to conserve the soil for food's sake. I am confident that you men who are adding the first requisite we need to put back into the soil, namely, limestone, are going to be good soil conservationists.

We hope that as a result of what we are discussing here you will add your strength and your conviction to make yourselves still better soil conservationists, not just because you are in the business of selling limestone, but because you understand the food problem as a soil fertility problem.



The International soil pattern shows the limited areas capable of providing protein similar to the soils of our Mid-Continent. Soil fertility for foods that feed and not acres is the better criterion for our agricultural service.

We hope you will not only be jealous of our soil nationally, but also that you will be compassionate and considerate in thinking soils internationally. We hope, however, that you will be a little jealous of our own soil fertility reserves before we become too generous and before we take on too much of the world in the way of feeding everybody.

We ought to look forward a bit and, though we are soil conservationists, let us realize that it is not only going to be calcium alone the soils need but, about the time we get the calcium problem solved, we are going to meet the others. Perhaps you want to begin thinking about the magnesium problem. I hope you begin thinking about some of the trace elements which your limestones can carry. I hope you will begin to realize that it will not be much of a task to put a little magnesium, or copper, or cobalt, or zinc into your limestone and haul one or all of these out at the same time you haul your limestone onto the soil. These trace elements are a fruitful field for some research by you. For example you could put a little manganese of the basic slag waste of some of the steel mills into the limestone and haul the manganese, with almost no extra cost. As producers of limestone you are also partially custodians of the soil by which all of us must be fed.