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PLANT AND ANIMAL NUTRITION IN RELATION TO
SOIL AND CLIMATIC FACTORS

Nutrition Via Soil Fertility According to The Climatic Pattern

By W. A. ALBRECHT, Ph.D.,
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Nutrition Via Soil Fertility According to The Climatic Pattern*

By W. A. Albrecht, Ph.D., Professor of Soils
College of Agriculture, University of Missouri

The human species seems to be slow in learning how to feed itself effectively. Its nutrition is not guided wholly by instinct, as is true of the lower animals, nor yet by design of its own sufficiently reliable to guarantee its survival. Degenerative diseases, as causes of death (U.S.), have risen from 39 per cent of the population in the decade 1920-29 to 60 per cent in the year 1948. During the same period the infectious and general diseases decreased from 41 to 17 per cent. (23).—See References, pages 30-31.

"Disease is so generally associated with positive agents—the parasite, the toxin, the materies morbi—that the thought of the pathologist turns naturally to such positive associations and seems to believe with difficulty in causation prefixed by a minus sign." (22).

We are slow to believe (a) that the entrance into the body by microbes is not necessarily by their overwhelming attack but probably their initiatory part of a task of disposal under the beginnings of death recognized earlier by them than by their pseudo-victim; (b) that much of what we call disease is nutritional deficiency; (c) that we do not retain in our foods and feeds all their nutritional values possible between their production and their consumption; (d) that the soil may be deficient in the contribution of the 14 or more indispensable inorganic elements; and (e) that the foods cannot have in them those essential inorganic elements absent in the soil growing them. Man's place at the top of the biotic pyramid may be impressive through its loftiness; but it is correspondingly hazardous in nutrition and thereby in survival in terms of the myriads of compounds and their chemical complexity because of man's dependence on the many services of collection and synthesis coming from below him through the animals, the plants, the microbes and finally the soil fertility. The soil is the point at which the assembly lines of all life take off.

Deficiencies Are the Expectable, Not the Unusual

If the evolution of higher life started in the seawater, its physiology represents an ionic complexity in equilibrium with that growth medium.

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The presentation of this subject before the Conference in Adelaide, Australia, and the exchange of related ideas with colleagues in science in that country were made possible through the approval of the National Research Council, Washington, D. C., and the support of the Carnegie Corporation, New York, N. Y. Gratitude for the opportunities is reported with pleasure.

And if soil is a temporary reststop of the rocks on their way to solution and to the sea, then man's evolutionary migration from out of the sea onto the land is one going against the current of soil development. Consequently, it is a migration toward nutrition on the level of the single rock contents. It represents the hazard of deficiencies certainly in the inorganic elements. These deficiencies are expectable when rocks consist of limited minerals and these in turn of limited numbers of elements. When of the 18 or more elements required by our bodies, only four originate in air and water while 14 or more must be supplied by the soil, and when any rock going to make soils seldom contains half that many, then man's evolutionary movement to land suggests the necessity of maintaining some life lines reaching from there back to the sea, or its fertility equivalent, for prevention of deficiencies of inorganic elements alone. Movement away from the sea's varied collection of elements suggests that deficiencies should be expectable in nutrition even in just the ash constituents of the body.

Equally as indispensable as the 14 inorganic elements are the 15 or more vitamins (12) going back to animals, plants, and microbes for their synthesis. These complex compounds have been too small in amounts present, too unstable in structural nature, and too baffling in chemical composition to become a part of the list of requisites for ourselves before but recent years. They render their services, not as parts of the body structure, but rather as tools and catalyzers in the many processes bringing about body construction. As catalysts, should we expect them to stand out before the reactions, of which they increase the speed, fail us and thereby bring about some biotic disasters? Recent research (28) suggests that the concentration of some vitamins in vegetables increases as the fetility of the soil growing them moves toward imbalance and shortages in the elements. If these are the facts, shall we be hesitant in postulating that vitamins climbed to recognizable concentrations and biochemical prominence because of the increasing inorganic deficiencies coming via the soil? Like the whip for the team of horses, which comes into more prominent use as the team is less equal to the load, shall we not see vitamins coming into prominence because of deficiencies and imbalances in the substances reacting under the stimulation of these catalysts?

Besides this significant number of 29 indispensables already listed as inorganic, soil-borne elements and vitamin compounds, we must have also ten specific amino acids out of a known list of more than twice that number. These ten are requirements as constructive parts of our body proteins. Proteins are the only compounds of the body that can reproduce and that can transmit life. The chemical reactions of living organisms are mediated by *enzymes;* the body activities are coordinated by *hormones;* some diseases are credited to *viruses;* and protection against many diseases is affected by *antigens.* All these different terms are specific names for body creations which in chemical composition can seemingly be classified as proteins (18).

Amino acids are synthesized from their constituent elements, not by our own bodies, but by plants and microbes. They are only collected, possibly simplified or transformed, and assembled into proteins by higher life forms. Animals must find their amino acid requirements in their rations, except as microbial symbiosis in their alimentary tracts supplements them. (17). Herbivorous animals are thereby limited to those soil areas where the

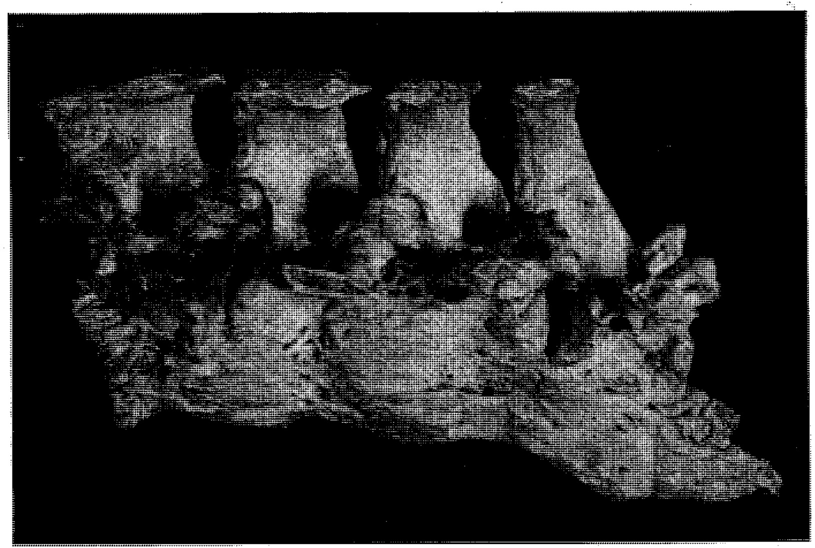

Fig. 1. Four vertebrae from the mid-back region of a shy-breeding cow that failed at an early age. Note the solidification of joints and suggestions of bone sacrifice with later but irregular replacements limited to those four vertebrae and the fifth one broken out (right). Collected from one in a herd on planosol soils given no fertilizer treatments.

fertility undergirds the microbes and plants in their synthesis of the animal's amino acid requirements. It is in these fundamental body-building, life-propagating aspects of making proteins in the vegetation that the soil elements of fertility take over the control. It is only recently that proteins have begun to come into their own (21). They will be doing so only slowly as long as we are content to classify as proteins the whole gamut of organics of which the nitrogenous residues of ignition in sulfuric acid are multiplied by a single arithmetical factor like 6.25 or some other simple number decided upon by our majority vote. Can knowledge of such loose construction prohibit irregularities and deficiencies in the propagation and reproduction of life founded on the construction so intricate and extensive as that of the myriads of protein molecules?

Our growing knowledge of nutrition has segregated also three fatty acids as specific requisites. These are fats with 2, 3, and 4 unsaturated bonds respectively. This chemical structure magnifies the ease and speed of either their oxidation or their hydrogenation. These reactions bring distinct chemical and physical changes converting them by the latter from oily liquids into solid fats. If their physiological essentiality should rest in this unsaturation, we need to raise the question whether the hydrogenation of our food fats is not defeating the purpose in our eating many of them. It also questions whether the numerous aerating manipulations of milking and pasteurization are not destroying the nutritional services by such unsaturated essential fats in milk. Such a hypothesis provokes itself (a) when we remember that the calf takes its milk by means of natural nursing equipment that excludes air most completely, and (b) when recent experiments in milking and processing in an atmosphere of nitrogen give a canned sweet milk that remains near its originally milked condition for days on the grocer's shelf (10).

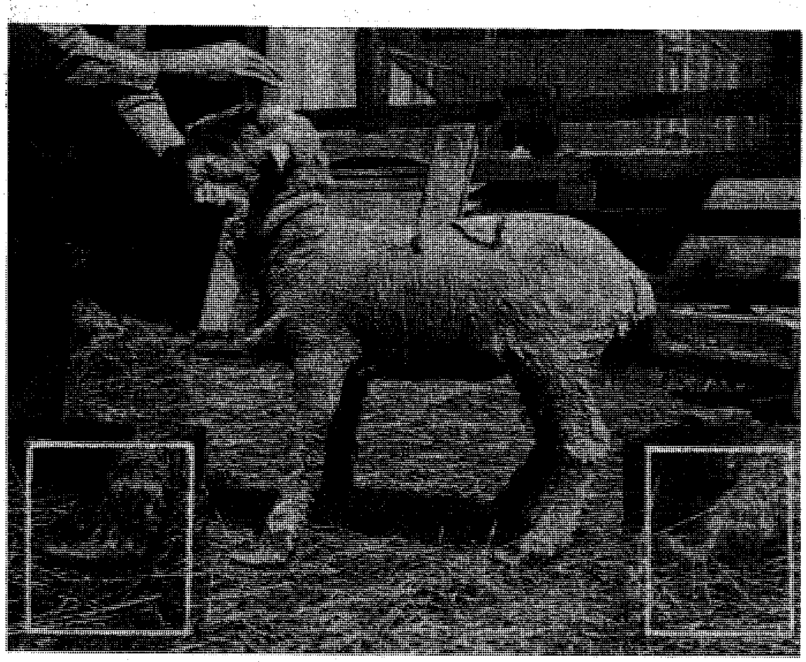

Fig. 2. The irregular hoof when fed timothy hay grown on level prairie soil (planosol) given no treatment suggests that this form of agglutinated hair reflects the nutrition as much as the wool does.

Our knowledge of the nutrition of ourselves and of many of our animals has already listed 14 (possibly more) inorganic elements coming from the soil as requisite for the assembly of four other elements from the air and water by the synthetic processes of microbes, plants, and animals providing us with food. Up to date, there are amongst the required compounds so synthesized in the biotic pyramid supporting us, 15 or more vitamins, 10 amino acids and 3 fatty acids. This is already a total of 46 specifically required and chemically characterized items in what would seem but the overture in the program by the growing science of nutrition. Shall we be startled by our failure to keep this list (and possibly many other items still unknown) completely assembled and in proper balance at all times for complete nutrition with its resulting good health? It would seem logical to believe nutritional deficiencies the expectable rather than the unusual.

When the soil fertility, i.e. the list of required inorganic elements—and possibly some organo-inorganic compounds—in the soil, is the foundation for the life pyramid of microbes, plants, animals, and man; and when the soil is the resulting product from rocks weathered by the climate; it seems most logical to look first for a natural pattern of nutrition of all life in accordance with the fertility of the soil; and then for this fertility in a pattern according as the climatic forces of the past and the present determine it. Such broader patterns of these basic forces should be helpful in elucidating and integrating the details of our nutrition which, if separated therefrom lose their significance or even escape us.

Soil Dynamics Control Nutrition

Creation of life starts with the lifeless, soil-borne inorganic elements. These serve to synthesize the meteorologically contributed elements along with themselves into the living organic compounds. It is from the soil that the provision of nourishment for all life takes its start. The rock-mineral mass of the earth and its conversion into soil determine whether the latter serving as that provider, is sufficiently diverse and active in terms of the inorganic, or ash, elements for support of animal life. In order to fulfill the requirements for this objective there are necessary:

(1) The rock-minerals in the sands and silts containing the 14 or more inorganic elements of soil fertility indispensable in our food supply;

(2) The rock-weathering processes, or the mineral breakdown by means of soil acidity to move these elements out of the fixed compounds into potentially active ions;

(3) The retention by adsorption on the colloidal complex within the upper soil horizons of those active elements against loss therefrom in percolating waters, but also in forms exchangeable to the microbes and the plant roots for the hydrogen or other elements they offer in trade (16);

(4) The exchange to the plant roots of each nutrient element in par-

ticular amount and ratio to others as permit their synthesis into the plant compounds for its growth and reproduction; and

(5) Their diversity in supplies and activities under continued renewals within limited soil volumes to guarantee the plants' synthetic delivery of carbohydrates, proteins, fats, vitamins, inorganics, etc., requisite for the nourishment of animals and man.

Hydrogen in the Soil Mobilizes the Nutrients

These dynamics of the soil make it function as a mineral reserve of the essential fertility elements in the sands and silts breaking or weathering

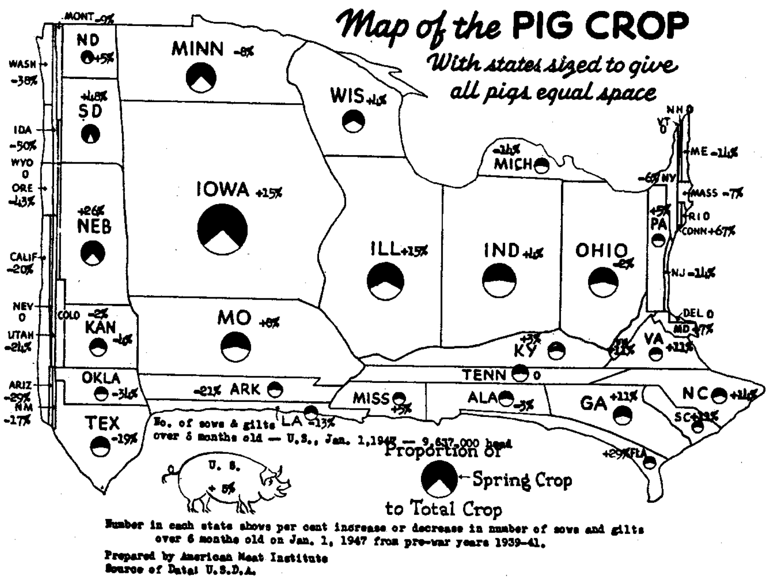

Fig. 3. The soils under high rainfalls producing carbohydrates more than proteins make animals with more fat. (American Meat Institute, Data from USDA).

out from there into ionic forms to be adsorbed on the clay-organo-colloidal complex, and moving from there to the microbial or root cells for their nourishment. In the opposite direction along that course, there is a movement of active hydrogen. This originates in the carbonic acid formed from the carbon dioxide of respiration by the living cells, to be adsorbed on the colloidal complex in exchange for other cations. This adsorbed hydrogen gives the colloidal complex an acid reaction. It makes this the reagent for speedier weathering of the minerals in the sand and silt reserves, or for the mobilization of their ionic contents to the colloidal complex for plant nourishment. It moves other cations into the plant roots more efficiently (4).

The migration of the elements from soil into the plant roots is then a highly variable behaviour. It should therefore result in different amounts of, and different chemical natures of, the food compounds synthesized by the plant. Variations in products compounded by the plants occur according to (a) the exchangeable supply in terms of degree of saturation of the clay's capacity and total amount of each nutrient element on the clay (15); (b) the ratio of the amount of each element in respect to the others on the clay (13); (c) the relative activity there of each ion according to its association with other particular ions (19); (d) the total amount of root surface per unit of soil volume (3); and (e) the metabolic performances

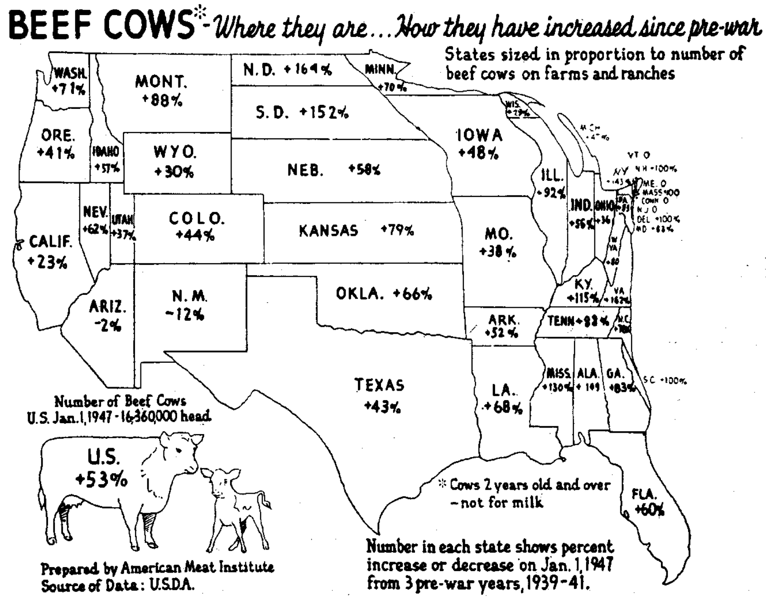

Fig. 4. The soils of the Mid-continent producing proteinaceous forages make animals with more protein rather than mainly fat. (American Meat Institute, Data from USDA.)

within the plant root according as these give different colloidal attributes to the root contents and the cell membranes enclosing them (14).

It is the variation in the fertility and the chemical dynamics within the soil supplying the nutrients to the plants, that gives the basic reasons why there are different plant species on different soils. It gives the reasons also why the same plant species on different soils should vary in the compounds it synthesizes and therefore in its delivery services of feeds and foods. It explains why on one soil—less fertile—a crop delivers mainly photosynthetic products, namely, the carbohydrates, while on another—one more fertile—the same crop delivers not only those fuel foods, but also the biosynthetic products like proteins, vitamins, organo-inorganic compounds and others. It gives these and others serving in body-building and reproduction because of more contributions from the fertility of the soil. Food in terms of more than fuel service is therefore dependent on the higher fertility of the soil.

Protein Potential According to Climatic Pattern of Soil Construction or Destruction

The major problem in feeding ourselves and our domestic animals is one of providing proteins in sufficient quantity and of complete quality. Such higher life forms merely assemble proteins from the ingested amino acids. These are synthesized from the elements by plants and microbes. Unfortun-

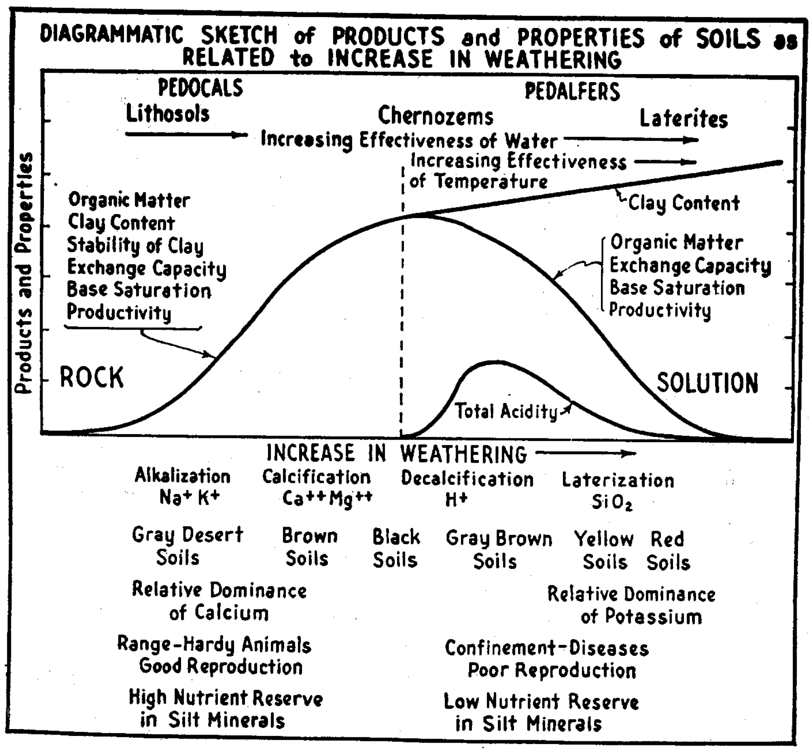

Fig. 5. Diagrammatic representation of the development of soil under increasing forces of weathering by rainfall and temperature. The maximum of rock breakdown, under clay saturation by nutrient cations, and only small amounts of acidity represent the fertile soils for protein production and good nutrition of higher forms of life.

ately, we have been too readily content to measure efficiency of our management of the soil fertility by the agricultural output of bushels and tons. Also, we have apparently assumed chemical composition of plants a constant according to plant pedigree. Bulk production has been generally accepted as a satisfactory criterion.

Consequently, when the decreasing fertility of a soil brought lowered tonnage per acre of an acceptedly nutritious herbage, like alfalfa (lucerne), we substituted another whose bulk production on that same soil was high. In that substitution there was the acceptance in the replacing crop of a higher concentration of carbohydrates and a lower one of proteins and of all the other special organic and inorganic compounds associated with, or requisite for, protein production by plants. Korean lespedeza *(Lespedeza striata)* or sweet clover *(Melilotus alba)* often replace alfalfa, for example, because the larger tonnage yields of the former over the latter on less fertile soils commonly are enticement for this substitution. This is the case especially when no more refined criterion than total nitrogen determinations is taken as the measure of their protein equivalents. It remains, however, for animal disasters (27), such as a poor gain, defective wool, and failing reproduction to characterize the lespedeza hay, and for animal deaths from bleeding in case of the sweet clover (coumarin) to point out the need for more specific criteria in judging the services of the soil fertility in the production by "juggled" crops. In terms of nutrition, it seems wise that we should turn to the total yield of protein per acre and its completeness in terms of at least the ten essential amino acids as the criterion of our successful management of the soil for feed and food production.

Amino Acids in Forages According to Trace Elements Applied To the Soil

More recently we have taken to measuring the total amino nitrogen (Van Slyke Method) and the concentrations of at least the ten separate essential amino acids in forages as influenced by the different nutrient elements of soil fertility (26).†

The concentrations of these amino acids in lespedeza hay, for example, were found to vary considerably according to the different soil regions of the State of Missouri, and with the fertilizer treatments used (Table 1). In alfalfa, grown on our humid soil requiring liming and other soil treatments for its successful crop use, the concentrations of these amino acids were increased by the applications of the separate trace elements, manganese and boron, and by a mixture of these with cobalt and zinc, all as supplements to the calcium (Table 2). They were also increased by the use of superphosphate or potash salts in conjunction with lime. This sug-

†This study was made possible through the encouragement and support of Swift and Company, Chicago, Illinois.

TABLE 1—AMINO ACID CONTENTS OF LESPEDEZA HAY ACCORDING TO DIFFERENT SOIL TYPES AND TREATMENTS (Per cent Dry Weight)

Soil type and Treatment	Valine	Leucine	Arginine	Histidine	Threonine	Tryptophane	Lycine	Isoleucine	Methionine
Eldon—									
treated	.89	1.05	.64	.37	.63	.29	.99	2.08	.09
untreated	.91	.97	.42	.34	.56	.20	.94	1.67	.08
Lintonia—									
treated	.92	1.03	.45	.34	.62	.27	.87	1.63	.07
untreated	.78	1.01	.32	.30	.54	.18	.87	1.68	.07
Putnam—									
treated	1.02	1.28	.71	.36	.63	.24	.89	1.89	.08
untreated	.98	1.28	.56	.50	.60	.22	1.00	2.26	.08
Grundy—									
treated	1.01	1.17	.62	.36	.69	.19	.79	2.00	.07
untreated	1.13	1.46	.45	.38	.67	.19	.93	2.00	.08
Clarksville—									
treated	.85	1.02	.34	.38	.58	.25	.93	1.59	.07
untreated	.94	1.19	.36	.35	.55	.21	.87	1.38	.07

TABLE 2—AMINO ACID CONTENTS OF ALFALFA HAY ACCORDING TO SOIL TREATMENTS WITH TRACE ELEMENTS (Percentage of Dry Leaves)

Plot No.	Treatment	Valine	Leucine	Arginine	Histidine	Threonine	Trpytophane	Lycine	Isoleucine	Methionine
1	Calcium	2.19	4.37	0.38	0.65	0.86	0.54	1.57	2.64	0.10
2	Calcium & manganese	2.40	4.89	0.43	0.80	0.95	0.64	2.12	3.63	0.24
3	Calcium & boron	2.13	5.55	0.41	0.72	1.07	0.85	2.13	4.09	0.17
4	Calcium & mixture*	2.59	5.24	0.41	0.83	1.01	0.67	1.87	3.44	0.22

*Mixture of cobalt,copper, zinc, manganese, and boron.

gests that these phosphate and potash salts may have been effective through their "impurities" consisting of trace elements. Spectrographic analysis of superphosphate revealed an extensive list of these in it to suggest that we may have been unwittingly applying trace elements extensively when superphosphate makes up such a large share of fertilizers.

Of particular interest amongst the effects by trace elements was the marked increase for trytophane and lycine. These two essential amino acids are usually so low in corn (maize) protein (zein), commonly grown on similar soil, as to demand that these be supplied to the corn ration in special protein supplements even for fattening more mature animals. Tests have not yet been undertaken with trace elements as fertilizers for corn to learn whether these specific amino acid deficiencies of zein would be overcome thereby.

Climatic Pattern of Soil Construction or Destruction Controls Ecological Patterns of Plants, Animals, and Man

Some general observations supported by critical studies prompted the concept that the climatic pattern of the soil fertility is providing either for the biosynthesis of protein and the photosynthesis of carbohydrates giving better nutrition via a balanced ration in general, or for mainly photosynthesis of carbohydrates and nutritional deficiencies. These provisions, that is, proteins and carbohydrates, or largely carbohydrates only, come by way of the different kinds of vegetation operating on the correspondingly either high or low nutrient base of soil fertility.

The ecological pattern of the virgin vegetation contained forests for no more than wood or cellulose as the crop from the soil on either the acid, highly-developed, fertility-deficient soils, or on the rocky, undeveloped soils, all with sufficiently high and regular rainfall to maintain trees growing all season. It contained prairie grasses and legumes with production of protein as well as carbohydrates on the mid-continental soils, that are well stocked with calcium and other fertility because of their moderate development by only moderate climatic forces. Such limited rainfalls mean intermittent summer droughts. They mean the survival only by such crops, like grass, tolerating periodic growth alternating with dormancy periods during the growing season. This moderate soil development leaves ample fertility which makes for grass as a highly nutritious feed because of the soil fertility rather than because of this crop's pedigree. Transplanting a grass agriculture to the humid, highly-developed soil does not necessarily argue for good nutrition of the poor beasts compelled to eat it there merely because of its good reputation as feed established elsewhere.

The distribution pattern of the virgin wildlife showed the herbivorous bison herds estimated as a total of once fifty million (24) on the mid-continental prairies. There were scattered small numbers on the humid but rarer calcareous soils now known as Kentucky's famous racehorse and bluegrass area. Likewise some of these active hulks of brawn and bone were in those limestone valleys of Pennsylvania where the high agricultural output per county breaks records today. The major post-bison area includes high-protein wheat, beef calves and beef cattle herds today. Such ecological patterns of virgin vegetation and wildlife superimposing themselves on the soil fertility pattern raise the question whether the food problem of shortage in animal protein can be solved without looking to the fertility of the soil.

The pattern of present cultivated crops has the better leguminous feed producers, rich in proteins and in the essential inorganic elements, also on soils developed under moderate rainfall and temperatures. Alfalfa, for example, requires much soil treatment for its even limited production and survival on highly weathered humid soils. Yet it grows readily and extensively on mid-western soils. This hay crop that in finely chopped form constitutes the major part of commercial livestock feeds, delivers higher nutritional service per bag when grown on those mid-continental than when on the eastern and south-eastern soils of the United States.

The protein concentration in the wheat grain is low on the humid soils in the eastern part of its area, and high on semi-arid ones in the western wheat area. This fluctuates for this single plant species from a low of near 9 per cent to a high of double that amount in no greater traverse

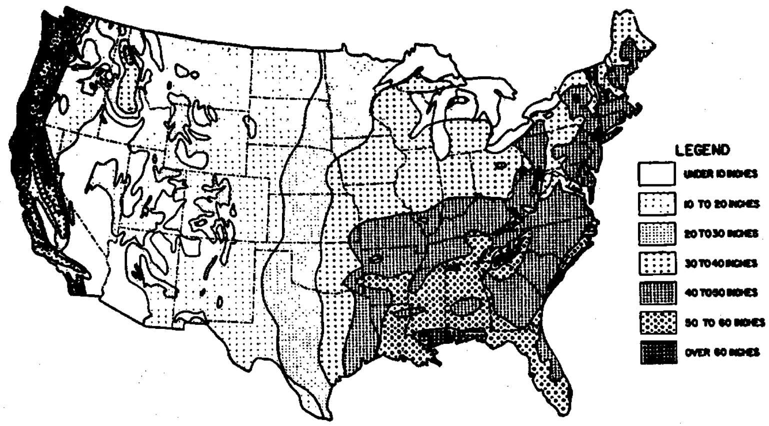

Fig. 6. Distribution of the mean annual precipitation in the United States. The higher rainfalls in the eastern part have leached the fertility from the soils, hence forests, as virgin vegetation, and carbohydrate-producing crops today more than protein-rich and mineral-rich products grow there.

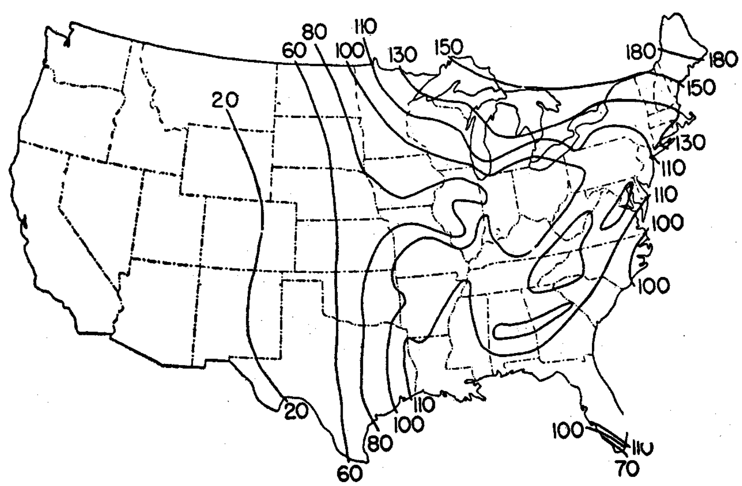

Fig. 7. Lines of constant ratios of rainfall to evaporation (times 100) give pattern to the fertility of the soil. They tell us that the Cornbelt soils with higher rainfall, but also higher evaporation accompanying, are similar to those farther west, in being more fertile and considered "prairie soils." (According to Professor Transeau, Columbus, Ohio.)

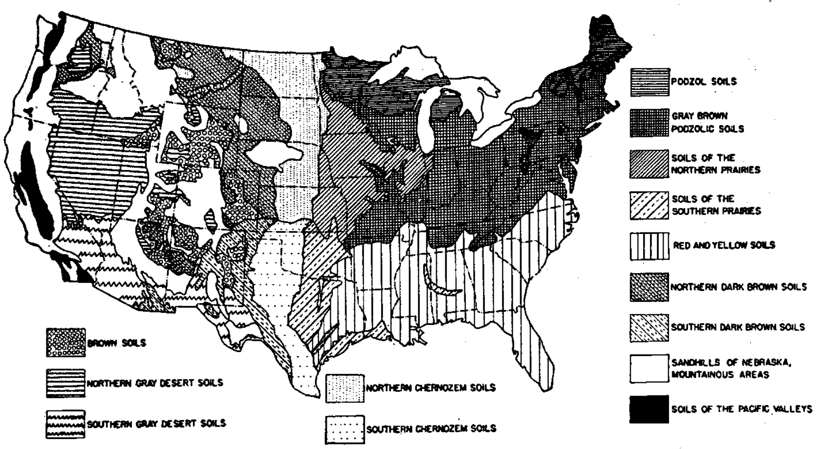

Fig. 8. The soil map of the United States is a composite of the map of rainfall and the map of rainfall-evaporation ratios. It is the soils that give an East and a West divided along the 97th meridian and divide the East into a North and a South. (Climatic and soil groups according to C. F. Marbut 1935.)

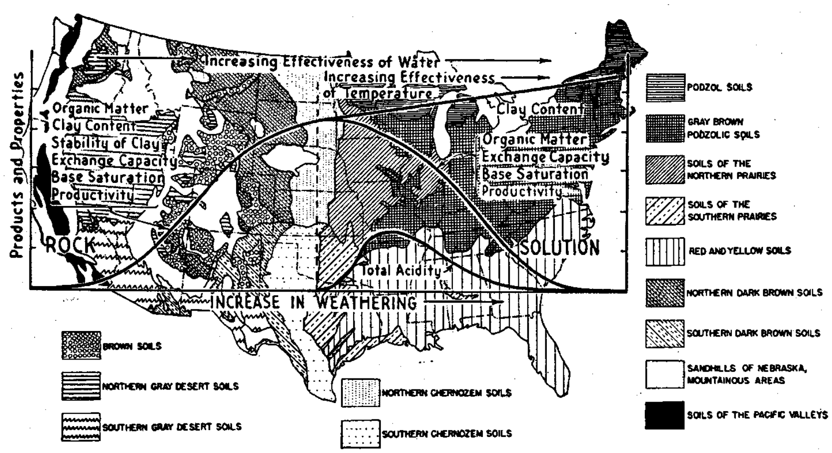

Fig. 9. The pattern of soil development of the United States shows the maximum soil construction and the minimum of soil destruction for protein and mineral delivery by crops in the Mid-continental area.

than across the State of Kansas from East to West, or from an annual rainfall of 37 to 17 inches. With increased cropping of wheat soils in that state the protein concentration is falling. The figures for the national protein standards for that food grain are being revised downward. At the same time, the bushels per acre of the increasingly more carbonaceous product are going upward to give record breaking totals of bushels very recently for the state.

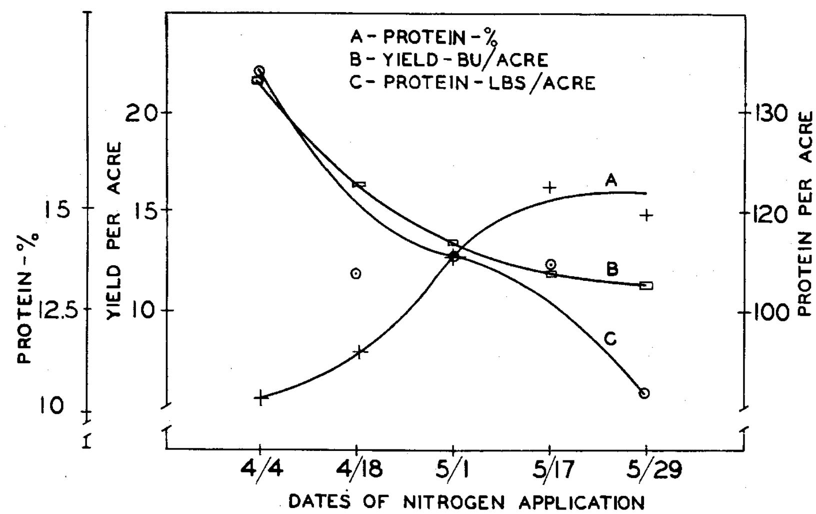

Fig. 10. The concentration of protein in the wheat grain is determined by the quantity of nitrogen in the soil and by the seasonal period in the plant growth at which it is supplied (Curve A). The yields of the total grain and total protein are higher as earlier and more generous supplies of nitrogen are made available. (Curves B and C, respectively.)

In the corn crop, grown on the more highly developed soils than those given to wheat, hybrid vigor has pushed up the bushels in total and per acre. However, during the last ten years the total protein concentration in that feed grain has fallen from an average of 9.5 to 8.5 per cent to say nothing of what might be happening to its array of specific amino acids. Quality of the same plant species varies not only with ratios of the elements in the fertility but with the decline in their totals of supply, as these facts emphasize. Such observations call for more critical studies of the protein potentialities according to the climatic pattern as it represents soil construction or soil destruction in terms of these requisites for good nutrition.

Carbohydrates Mainly and Proteins Also In Crops Depend On the Ratios of Exchangeable Calcium to Potassium

A study of the inorganic composition of the crops and native plants growing on soils that are (a) slightly developed in the western United

States; (b) moderately developed in the Mid-continent, and (c) highly developed in the East, North-east and South-east, established the significance of the calcium-potassium ratio (also calcium-phosphorus ratio) (2) in the crop composition as a reflection of the same ratio of these fertility elements in exchangeable amounts and in relative activities on the colloidal clay complex (5) (Table 3). A wide ratio of these occurred in the forages in western United States on the recognized calcareous soils. On coming eastward it was narrower for the crops on moderately developed soils. It was still narrower for forages and other crops grown on the highly developed, acid and calcium-deficient soils on coming still farther east and south-east toward higher rainfall and temperature.

TABLE 3—COMPOSITION OF PLANTS ACCORDING TO DEGREE OF SOIL DEVELOPMENT

	Plants growing naturaly on soil developed		
	Slightly (38 cases)	Moderately (31 cases)	Highly (21 cases)
Dry matter contents as			
K_2O %	2.44	2.08	1.27
CaO %	1.92	1.17	0.28
P_2O_5 %	0.78	0.69	0.42
Combined %	5.14	3.94	1.97
Amounts relative to highly developed soil			
K_2O	1.9	1.6	1.0
CaO	6.8	4.1	1.0
P_2O_5	1.9	1.6	1.0
Ratio K_2O:CaO	1.2	1.8	4.5

Here is well illustrated the relatively more rapid removal from the soil during climatic development of its supplies of exchangeable calcium and some other nutrient elements apparently associated in similar physiological functions than of the potassium. The former is generally associated more particularly with the fabrication of the proteins from the carbohydrates by the plant's life processes. The latter is generally associated with the plant's fabrication of the carbohydrates. As the soils, then, are not yet developed to provide exchangeable calcium generously, or are more highly and excessively developed to remove it, their exchangeable nutrients on the colloidal complex represent supplies and activities in such ratios, particularly of calcium to potassium, as to provide a fertility imbalance which is feeding the forage sufficient potassium for carbohydrate production and construction of the plant as a bulk-producing factory, but as little more. It fails to provide the calcium and its associated elements, presumably including the trace elements, requisite for the conversion of these energy food values into proteins and reproductive possibilities.

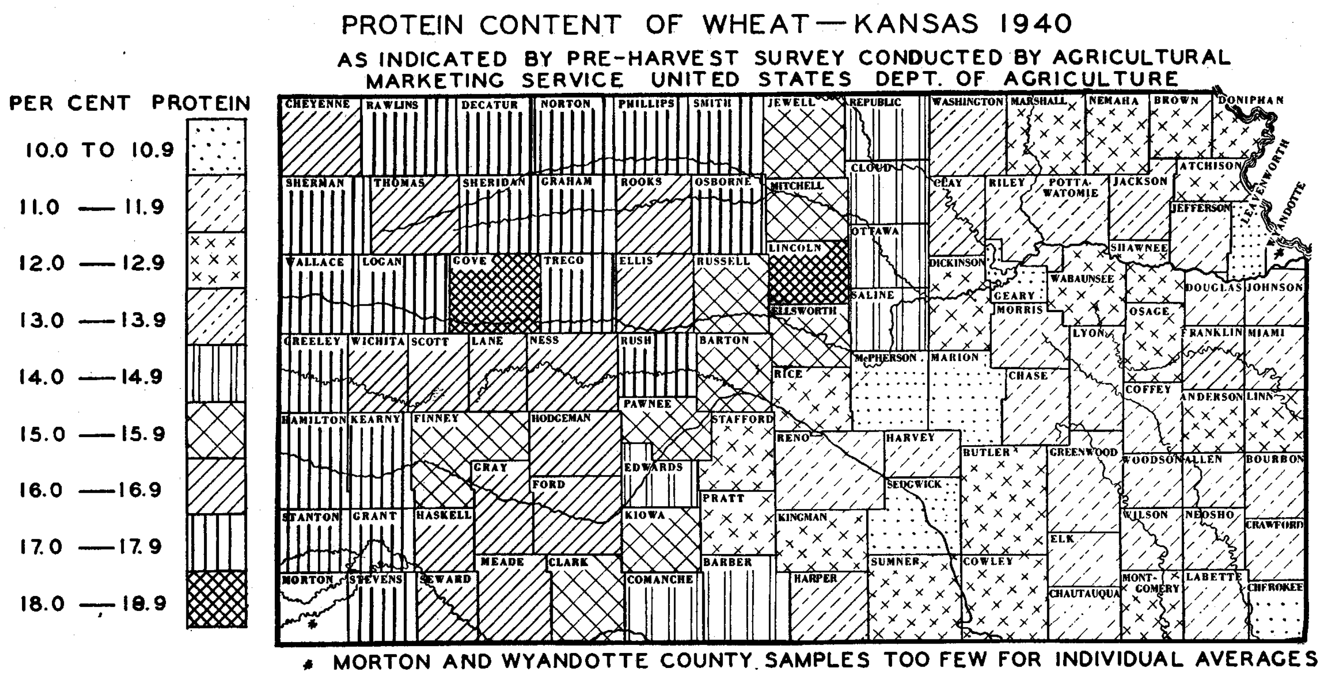

Fig. 11. Protein concentration in wheat in Kansas, 1940.

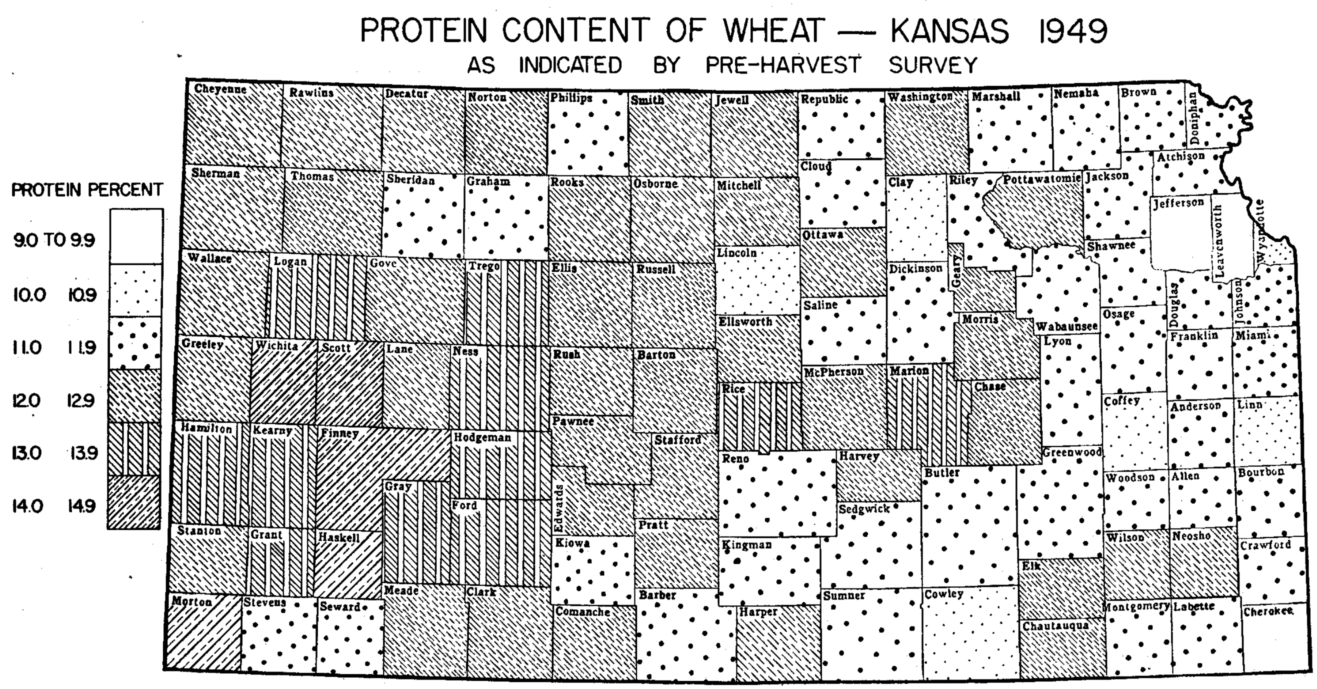

Fig. 11. (Continued). Protein concentration in wheat in Kansas, 1949.

It is only in the central United States, then, where there was sufficient of soil construction but a minimum of soil destruction, or where the ample mineral reserves and the suite of ions adsorbed on the clay gave protein production in the virgin short prairie grass to make big herds of bison and the similar but dwindling fertility supples in modern times to represent high protein wheat and beef cattle under our cultivation. It is there that nutrition is of a high order because of the specific soil fertility array originating from the particularly fortunate combination of (a) glacial and windblown mineral mixtures, and (b) moderate rainfall in the temperate zone developing fertile soils from them.

One needs only to recall the forests on the less developed and rocky soils to the west of this mid-continental area. Then there are likewise the forested areas to the extreme East with hardwoods adjoining the prairies on their east. One needs also recall that the conifers, which are much lower in the evolutionary scale, are to the Northeast and the Southeast. This coniferous vegetation occurs on the acid, fertility-deficient soils with clay of high exchange capacity in the Northeast. It occurs on the lateritic, fertility-deficient, but non-acid soils of low exchange capacity to the Southeast and the tropics. All these are areas where deficiencies in nutrition may well be expected under cultivation today when the virgin crop represented little or no protein and the wildlife was extremely sparse, if not entirely absent.

The numbers of tooth caries per inductee into the United States Navy in 1942 tell us that the ecological array of the human is part of the pattern of climatic soil construction and destruction (9). Arranged by longitudinal soil belts two states wide, the inductees from the Mid-continental, protein-producing soils exhibited 12.08 caries per mouth. On going westward from there to soils of less construction and then to the humid West Coast, the figures were 13.10 and 15.50, respectively. On going eastward from the Mid-continent to soils exhibiting increasing soil destruction the numbers of caries per mouth were 14.95 and 17.55, respectively. These facts about this exposed part of the human skeleton tell us that the human species too takes an array in these health aspects according to the climatic pattern of soils.

Extensive experimental work has been carried out using the finer colloidal clay fraction as the medium for controlled plant nutrition and growth. This means of research permits control of the combinations or ratios of exchangeable cations (some anions) as well as the total amounts offered the plant for its nutriton (8). These studies have demonstrated the wide diversity in the plant's synthesis and storage of sugars, starches, (11) vitamins, proteins, and amino acids according to the ratios and activities of the exchangeable ions on the colloidal complex, and seemingly to the

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

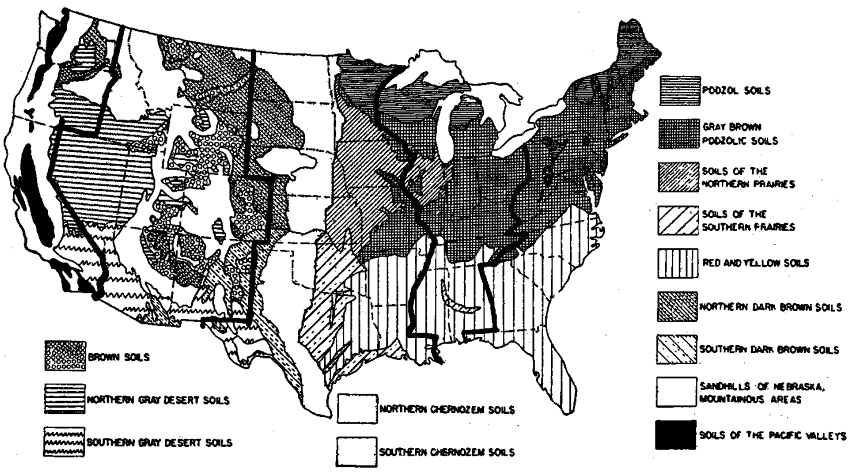

Fig. 12. The concentration of dental caries per inductee into the United States Navy 1942 gives a reciprocal curve of that for soil development under the climatic forces. The minimum of caries is in the Mid-continental area of maximum of soil construction. There is an increase in caries in going westward from there to soils less developed, and more so in going eastward to soils more highly developed.

dynamics of the plant root. The wider calcium-potassium ratio of these activities on the soil colloid favors protein production and higher concentration in the crops giving less total forage yield (Table 4). Conversely, the narrower calcium-potassium ratio gives little protein production and much bulk of forage. Many other variations in plant composition have been demonstrated because of the variation in the ratios of the exchangeable or active fertility of the soil. No credence can be placed in yields of merely more bulk as a reasonable index of more complete nutritional service by the forages. Their nutritional values depend on the fertility of the soil by which they were synthesized.

TABLE 4—INCREASE IN WEIGHTS OF SOYBEAN PLANTS BUT A DECREASE IN TOTAL NITROGEN (Protein), PHOSPHORUS AND CALCIUM IN THE HAY CROP WITH WIDENED POTASSIUM-CALCIUM RATIO IN THE SOIL GROWING THEM

Exchangeable cations. M.E.			Crop weight	Nitrogen		Magnesium		Calcium		Phosphorus		Potassium		K%/
Mg	Ca	K	gm.	%	Mgm.	%	Mgm.	%	Mgm.	%	Mgm.	%	Mgm.	Ca%
5	10	0	14.207	2.86	407	.36	52	.74	105	.25	39	1.01	150	1.36
5	10	5	14.592	2.56	372	.36	54	.32	46	.18	26	1.90	285	5.93
5	10	10	17.807	2.19	390	.30	55	.27	48	.14	25	2.15	584	7.96

Seed content in mgm. N = 364, Mg = 16.7, Ca = 12.2, P = 39.4, K = 171

Fig. 13. Protection against disease is helped by better nutrition. Attack by a fungus disease was lessened and prohibited as more hydrogen-calcium-clay, pH 4.4, was mixed into the sand (left to right) to supply these soybean plants with more calcium and to help them in their nutrition.

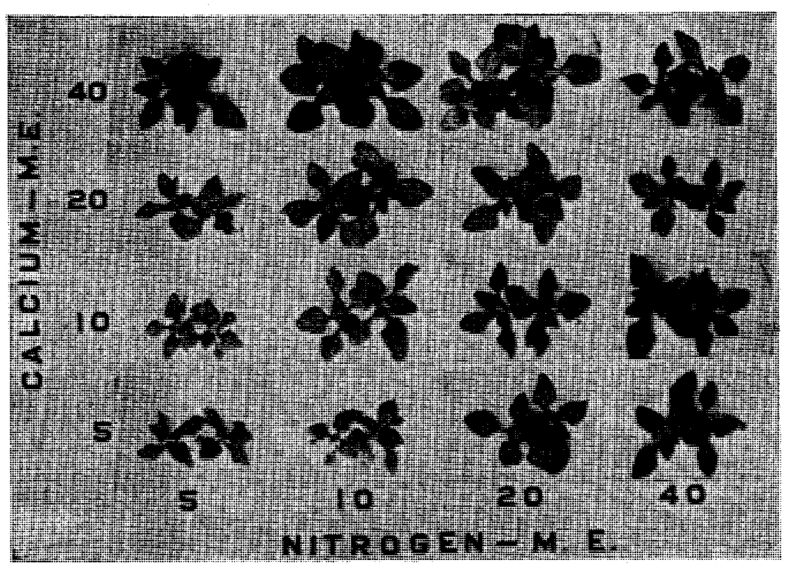

Fig. 14. Increasing the nitrogen, (vertical rows, left to right) in the soil growing spinach protected the plants (two rows on right) from attack by the thrips (Heliothrips haemorrhoidales). Increasing the calcium (horizontal rows, bottom to top) made them less damaging (left two rows) suggesting the protection against this insect brought about by the fertility elements favoring protein synthesis in the plants.

Animal Choices and Feeding Trials Emphasize Animal Nutrition Via Soil Fertility

Observations of choices by animals at large, and under control, using feeds grown on soils given different treatments, point out the animal instincts for selecting not mainly carbohydrates for laying on of fat, but proteins, inorganics, etc., for body growth and reproduction. Hogs given choice of different corn grain in separate compartments of the self-feeder discriminated against that grown with green sweet clover plowed under just ahead of it, and in favor of that with plowed-under residues of sweet clover as a seed crop the preceding year. They were discriminating at the same time against the additions of increasing fertilizers on the soil in the former and in favour of them in the latter that made correspondingly larger yields of both sweet clover and corn in both cases. It was not the increasing yields of the crops, therefore that invited the particular choice. Nor was it increasing fertilizers in the soil. It was a distinct animal response, via its feed, to soil dynamics involving several aspects of soil treatments.

Animal behaviours are now undergoing much closer observations. Reports of animal choices according to the soil are becoming numerous and the various explanations of the causal relations are legion. As assayers, our animals are making excellent biochemical contributions (7). The animal's instinctive choices of its grazing according to the soil fertility, but its ingestion of almost any plant on fertile soil, irrespective of our classification of it as a weed or as a commonly accepted herbage, points out the animal's acceptance of crops according to the soil's synthetic services through them and not to the reputation founded purely on plant pedigree or scientific name. Pigs and chickens have always been running for the cow's droppings. We have only lately come to imagine that they might have long been recognizing there the "dung factor" recently considered a necessity in the poultry rations, the "animal protein factor (APF)," the "anti-anaemia factor," and all the other ascriptions to what looks like the cobalt-containing Vitamin B_{12} (1). That the pig and the chicken needing "APF" should recongnize the synthetic services even as late in the series as those in the cow's alimentary tract, in bringing soil, microbe, plant and herbivorous feeder into a complex symbiotic process of feed production for them, is suggestion of the many possibly complicated integrations by which nutrition depends on the soil.

Experimental trials with ewe lambs demonstrated differences in their growth rate according as the soil growing the hays (soybean and later lespedeza) had been given (a) no treatment, (b) superphosphate, and (c) lime and phosphate (6). During the 63-day feeding period using constant amounts of concentrates per head per day along with hay *ad libitum* but consumed at the constant rate of 2.1 pounds per head per day for all hays,

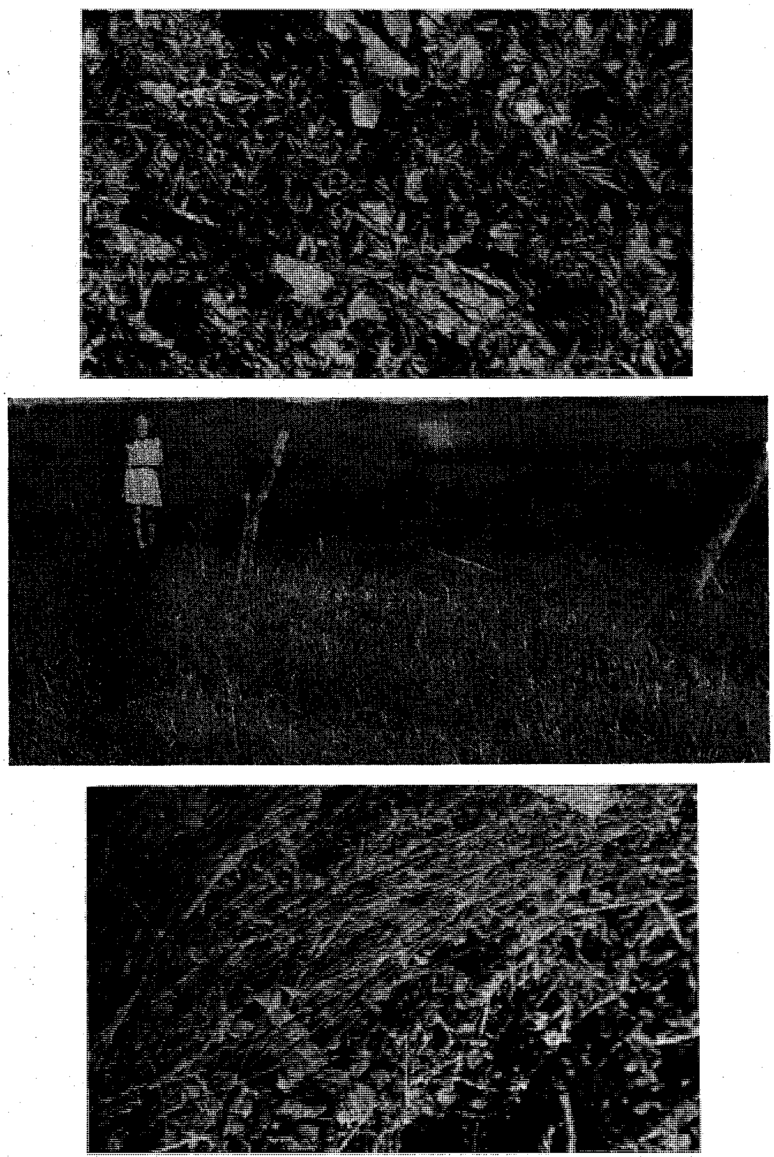

Fig. 15. Cattle disregarded virgin prairie grass on unfertilized soil (lower photo and foreground of center photo) on going through it to the various weeds and grasses they preferred on the fertilized field abandoned on account of labor shortage (upper photo, background of center photo). Photos by E. M. Poirot, Golden City, Missouri, USA.

Fig. 16. The nutrition of the lambs is reflected in the fleece (left photo), in the wool sample (center photo), and in the dried wool after scouring it in dilute alkali (right photo) according as the hay was given only superphosphate (lower photos) or both superphosphate and limestone (upper photos). Wool in the lower photos could not be carded. It is disintegrated as shown (lower part of right photo).

there was a total growth of 8, 14, and 18 pounds per head, respectively, for the soil treatments listed. The wool of the sheep showed differences in yolk. It held up during the scouring process only where both lime and phosphate were the soil treatments. No tests were made as to possible differences in dye reactions. During the following mating season only those ewe lambs fed on the hay with lime and phosphate on the soil came in lamb.

The larger yields of hay on lands given the two treatments permitted trials with each as feed for three male rabbits serving for artificial insemination purposes (6). Those males, fed hay given only phosphates, declined in their volume of semen delivered, in its concentration of spermatozoa, and in their viability. These males finally were so indifferent sexually as to refuse to breed a female in oestrus. No decline in sexual ambition or activity was evident for those rabbits kept on hay grown on soil with lime and phosphate. The hays for the pens were later interchanged. In only three weeks this latter group became indifferent and refused to mate with the female in oestrus, while the originally indifferent ones became active. Three weeks were sufficient for these animals to be disturbed in their mating potentialities by the forces coming up through these herbages under control of the fertility of the soil.

Rabbits fed the same variety of hay from the major soils with and without treatments in an area as extensive as the State of Missouri demonstrated wide differences in growth, bone development, and body physiology according to the soils and their treatments (20). Originally as uniform as possible in breeding and selection they were widely different for the different soils after a short feeding period. We are slow to see the soil in control of the characters of the animals while clinging to a traditional faith in breeds and pedigrees as determiners of animal body form.

Human Ailments Invite Their Consideration As Deficiency Diseases Going Back To the Soil

When vitamins may be simply defined as something that will kill you if you don't eat them, we have the beginnings of the belief in ourselves possibly being killed by many things we fail to eat. Deficiencies in nutrition are gradually coming into consideration as causes of poor health. However, it is at a slow rate at which those deficiencies are being considered as originating in the soil, either directly as a shortage of indispensable inorganic elements, or indirectly as compounds fabricated through their help in microbes, plants, and animals.

In order to test the hypothesis that such a baffling ailment like brucellosis in animals and man may be due to deficiencies, particularly of the trace elements, in the soil, Ira Allison, M.D., Springfield, Missouri, volunteered to cooperate and try some trace element therapy on afflicted humans as was suggested by Francis M. Pottenger, Jr., M.D., of Monrovia, Cali-

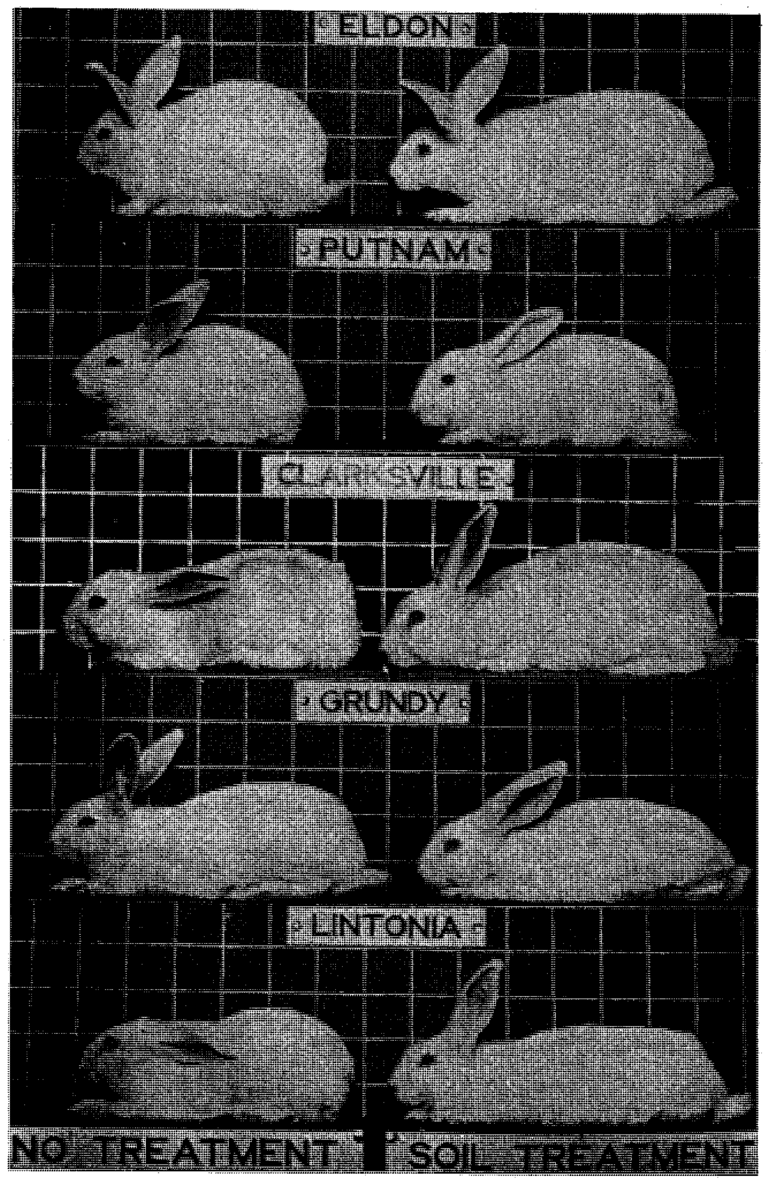

Fig. 17. Lespedeza hays grown during the same season on outlying experiment fields representing five different soil regions fed to ten lots of initially uniform weanling rabbits made wide differences in the animals after a short feeding period of six weeks.

fornia (25). Dosages of manganese, copper, cobalt and zinc under enteric coating have been used on more than one thousand brucellosis patients to date. Other ailments have also been included. The changes in the blood picture and other clinical aspects coupled with the patients' reports of improvements in health have been most encouraging with hope for relief from this disturbing ailment. This hope includes amelioration of other ailments, like arthritis, allergies, anaemia, eczema, angina, etc. as possibilities.

Experimental farm trials with soil treatments using trace elements for dairy cows are under way.‡ Greater regularity of conception and heavier milk output seem to support the human evidence that some of the indispensable inorganic elements are not coming sufficiently from the soil and are giving us health troubles even if they are not killing us because we don't eat them.

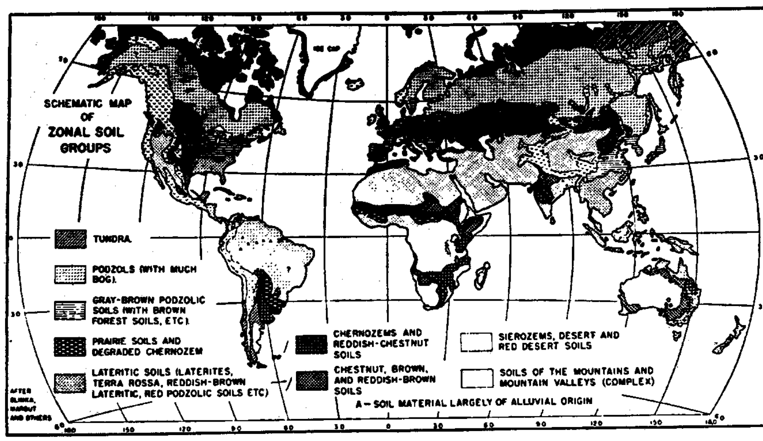

Fig. 18. The soil map of the world delineates the limited areas that produce high-protein wheat and meat. Such fertile soils are factors in making their possessor nations play their parts among the "powers" of the World. (Permission of C. E. Kellogg and The MacMillan Company.)

Good Nutrition Calls For Conservation of Soil Fertility

Gradually our reasoning about proper nutrition is leading us back to see the fertility of the soil as possible cause of deficiencies in our nourishment. Soil science in elucidating the soil dynamics points out the limited delivery by any one soil of even the inorganic indispensables. The climatic pattern of the under—or over—development of the soil demonstrates the limited soil areas where proteins can be synthesized, and then not neces-

‡Several trials with farm animals as the measuring means of the fertilizer effects via the soil in various parts of Missouri are underway through the support of the following: Schrock Fertilizer Service, Congerville, Illinois; Coronet Phosphate Company, New York, N. Y.; Spencer Chemical Company, Kansas City, Missouri; Tennessee Corporation, Atlanta, Georgia; and International Minerals and Chemical Corporation, Chicago, Illinois.

sarily with complete array of essential amino acids. Trace elements, only recently recognized, seemingly play a role in the synthesis of these. Trace elements are deficiencies for animal health and for human health, too. Insufficient criteria in choosing our crops and the declining soil fertility are pushing up their carbohydrate and pulling down their protein provision for us. Animals by their choices and by their health defects are demonstrating that their nutrition is a part of the soil fertility pattern. Military records of human health conditions also point back in that direction.

We are slowly coming to believe that much that we now call "disease" should be more correctly labelled nutritional deficiency. As this is more widely granted, there is a growing appreciation of the importance of the soil fertility in nutrition in general. Such recognition is making each of us more ready to take some responsibility in conserving the soil by which all of us want to be well fed and thereby healthy. It is also putting less emphasis on fighting disease and more emphasis on its prevention by better foods grown on better soils.

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