The Vital Earth News

Agricultural Edition

Volume IV, Number 2 **Vital Earth Resources • Gladewater, Texas** **Summer 1999**

Oklahoma: Death of a Soil

The following is excerpted from Chapter 10 of* Soil and Civilization *by Edward Hyams (Harper and Row, New York, 1952.

The settlement of the European North Americans upon the virgin soils they overran took place with fatal rapidity. It is almost true to say that whereas in A.D. 1800 North America west of the original thirteen colonies was empty but for a couple of hundred thousand, if so many, Stone Age tribesmen, by 1900 this vast country was already full of white farmers at a level of material culture comparable with that of Europe and in some ways surpassing it. Only the most massively stable soil could stand the sudden and exhausting draft upon fertility which is represented by this meteoric rise in material wealth. But it should be emphasized that the farmers in question were not conscious of doing any damage: they were simple and honourable men with a worthy purpose, that of keeping their families in bread and independence by the sweat of their faces ... In order that they should do this it was deemed necessary that each family hold a farm of 160 acres, although how this figure was arrived at seems to be obscure.

The American pioneer peasants were not seizing made-land but virgin soil. Faced with a choice between park-land, forest and *steppe*, they naturally swarmed towards the latter, for it offered few natural obstacles to the plough, and seemed to have been made for just such a contingency as the sudden arrival of men far advanced in agricultural techniques. But land which in semi-arid conditions and in a state of nature, offers few natural obstacles to the plough, is land which will not long stand ploughing; and ought not be ploughed....

When a community of Europeans colonizes virgin soil its members are neither willing nor able to go through the whole process, requiring some hundreds of years, which transforms a natural soil into an artificial one of great fertility and stability, such as that of northwestern Europe, capable of supporting a very high standard of material wealth. The

The plowing of portions of the Great Plains, which should have been left in native grasses, led to tremendous wind erosion that, at one point, sent a cloud of wind-driven dust as far east as Washington D.C.!

See To Desert, page 6

Soil Compaction and Rooting

A Conversation with Albert C. Trouse, Jr.

by Paul W. Syltie, Ph.D.

You may recall the article "Soil Compaction -- The Hidden Enemy" in the Winter, 1997 issue of *The Vital Earth News*. In that article I emphasized the pervasiveness of soil compaction and how greatly it affects crop growth and yields. This article continues that all-important subject from the level of one of the prominent USDA experts in soil compaction: Albert C. Trouse, Jr.

I met with Al Trouse of the National Soil Dynamics Laboratory, Auburn, Alabama, in March of 1988 at Austin, Texas, to discuss his experiences with research in tillage and compaction. His knowledge of soil compaction and rooting proved to be impressive indeed!

Note how the soil becomes compacted severely enough beneath wheel tracks and machine pressure to prevent root penetration.

Soil compaction is a vastly overlooked problem in crop production, stealing millions of dollars from farmers in lost production, and fertility and pesticide losses. The reason for this loss is due to greatly reduced root growth. Average compaction will reduce root growth from three inches per day to only one-half inch per day, only 8% of the growth compared to root extension in well-structured soil. A root can penetrate an oxygen-deprived environment about one inch, due to cell elongation, but if no oxygen is found the rootlet stops growing. Cell division stops with-

See Compaction Slows Roots, page 3

"Natural Agriculture" Really Pays!

Two recent reports from the prestigious journal *Nature* (November, 1998) show how an agriculture oriented towards the laws of nature really works in today's world. A 15-year study by the Rodale Institute (USA) examined three different systems:

1 **Conventional.** Typical commercial fertilizer and pesticide inputs in a corn/soybean rotation.

2 **Organic with livestock.** Manure used as the sole fertilizer source for corn, from cattle fed on the corn, and no pesticides.

3 **Organic without livestock.** Legumes for nitrogen production with corn, and no commercial fertilizers or pesticides.

Over a 10-year period the three systems showed little difference in yield (less than 1%), and were about equal in profitability. However, the organic with livestock system was significantly superior in soil fertility to the conventional system, and a bit above the organic system without livestock. The conventional system reduced soil fertility, and had allowed 60% more nitrate to leach into the groundwater than the other systems.

... soil nitrogen and soil organic matter increased by 120% over the 150 years for the manured plots ...

The second study is a review of 150 years of work at the Rothamstead Broadbalk Experiment Station in England. Wheat yields on manured plots averaged 3.45 tonnes/hectare, while commercial NPK plots yielded an average of 3.40 tonnes/hectare.

Moreover, total soil nitrogen and soil organic matter increased by 120% over the 150 years for the manured plots, but by only 20% for the commercial NPK plots. Clearly, manure plays a highly important role in the improvement of these English soils, while maintaining yields at high levels.

Manures, cover crops, and legumes in rotation are shown once again to greatly enhance soil characteristics and yields. By conforming to the laws of nature, we can be assured of long-term productivity of our soils. ■

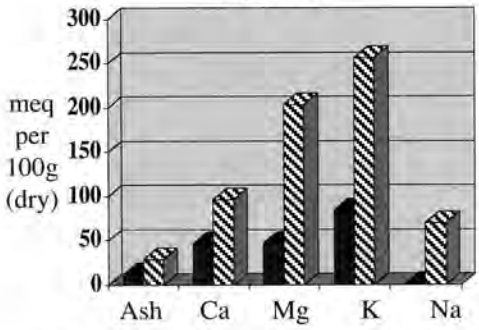
Great Variations in Crop Quality

Variety and Environment Greatly Modify Nutritional Value

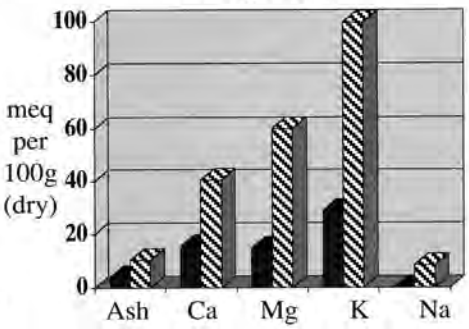
By Paul W. Syltie, Ph.D.

Many farmers and homemakers do not understand how greatly the nutritional value of food crops can vary. In a summary article by Firman Bear in *The Land News* (1949), a review was made of a study on the mineral composition of certain vegetables grown commercially in Georgia, South Carolina, Virginia, Maryland, New Jersey, New York, Ohio, Indiana, Illinois, and Colorado. Efforts were made to select the same variety for sampling at each locality. The soils varied rather dramatically from north to south, and east to west, the soils of the southern and eastern areas being highly weathered and leached, and soils of the central and western states being much more mineralized and less weathered.

Spinach



Snapbeans

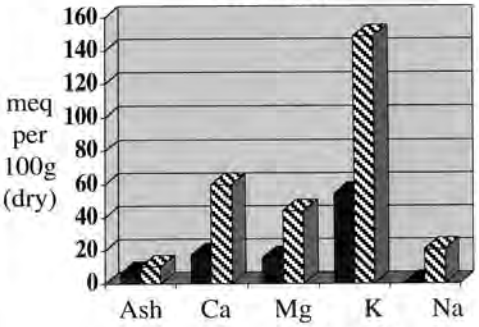


LEGEND
Right bar=Maximum value
Left bar=Minimum value

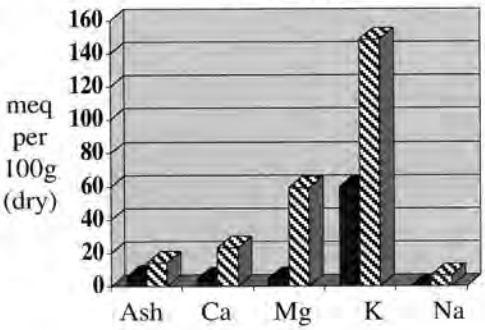
Crops from the western states -- especially Colorado -- tended to have higher mineral levels, while crops grown in the East and South had lower minerals. However, what was especially interesting was the **great variation** in mineral levels from the crops grown in all areas under various local farming regimes. Note the five graphs.

The message of this data is that since we can influence plant composition so readily, we ought to maximize it. ■

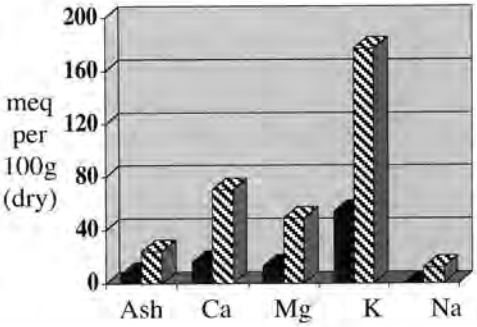
Cabbage



Tomatoes



Lettuce



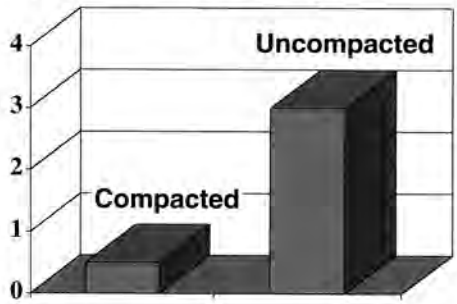
Compaction Slows Roots to One-Eighth!

Continued from page 1

out oxygen. With less root extension comes less water and nutrient absorption, and consequently greatly reduced growth and yield.

It is critical to initiate growth early in the plant's life cycle, since the "grand

Root Growth Per Day, Inches



period of growth" -- when most root extension occurs -- is from three to nine weeks after planting. If most of that growth window is missed, then root and top growth are both suppressed and yields suffer.

To illustrate the dramatic effect compaction can have on crop yields, he quoted a study from the Piedmont area of North Carolina. An entire field received

The only significant restriction to crop growth due to compaction is a lack of oxygen in the root cells.

enough fertilizer for a 600 bu/acre corn yield. One half of the field was purposely compacted and yielded about 100 bu/acre, while the other half was left uncompacted; it yielded about 400 bu/acre.

The only significant restriction to crop growth due to compaction is a lack of oxygen in the root cells. This is not to say that root penetration is not more difficult with compaction, but if oxygen could find its way to roots even in a compacted situation the roots would still penetrate. Dr. Trouse indicated that adequate oxygen in the root zone will favor plant health, since...

(a) beneficial microorganisms will tend to outcompete pathogens under aerobic conditions.

(b) the anaerobic environment is more favorable to most pathogens.

A vigorous growth of aerobic (oxygen-loving) microbes is essential for the formation of a strong soil structure, which implies a soil that has many large pores which allow for the rapid movement of air and water. Bulk density (weight of the soil/volume of the soil) is important for root extension only in the sense that a low density reveals there are many pore spaces which allow for rapid air exchange. Extremes of bulk density of 0.03 to 3.1 g/ml (a normal soil is about 1.2 to 1.5 g/ml) can allow excellent root growth provided enough oxygen can proliferate into and through the root zone. Contrary to the idea of some, even a very high CO_2 level around the roots will not impede extension as long as oxygen remains at or above 12%.

Moreover, it is the **availability of oxygen** that is so important to roots, not just the absolute percentage in the soil gas phase. If the oxygen content of the soil air is very low but the flow is good, the roots will grow very well. Stagnant soil air, typical under compact conditions, leads to reduced root growth since oxygen is quickly used up. Under such root stress the leaf stomata close and leaf metabolism slows greatly, usually when sunlight energy is at its peak during midday. Rain will renew oxygen in soil by "flushing" the system, revitalizing root extension.

Root cells will divide under drought stress if plenty of oxygen is available, but the cells will not expand, since water is limiting. When water arrives, the cells will elongate and allow root extension. On the other hand, if oxygen is limiting under drought conditions even cell division is halted.

To allow roots to grow **stay off of the soil**! Dr. Trouse advocates limited wheel traffic ... traveling in the same track each time the tractor or machine traverses the field. Most damage from wheeled vehicles comes from driving on tilled soils, but moldboard plowing also has its problems. Because the tractor tire oftentimes rides in the furrow, compaction is created along that pathway, but the plowshare itself can compact a layer. The total effect of the plow and tractor is the creation of a plowsole, a layer of collapsed soil macropores at

It is critical to initiate growth early in the plant's life cycle ... from three to nine weeks after planting. If most of that growth window is missed, then root and top growth are both suppressed and yields suffer.

plow depth which impedes air and water movement. In addition, plowing breaks the "structural continuum" of the profile, creating a barrier to the movement of water upward through capillary action.

A good crop can grow with only eight inches of rainfall provided the rainfall that does fall soaks in **where** it falls. Compact soil will not absorb much water. Once the minimal macropore space is saturated the remainder runs off and is lost, carrying with it lost yield potential and rich topsoil ... which further limits future yields. Because water is usually limiting to crop production in parts of the Corn Belt, it is critical that rainfall soak into the subsoil for storage for the next year's crop. If the soil is

Nothing beats a well-structured, high organic matter soil that is replete with many macropores, and easily exchanges air and water for maximum plant growth.

Go to Compaction, page 6

15-Minute Soils Course

Lesson 9: The Soil Foodweb

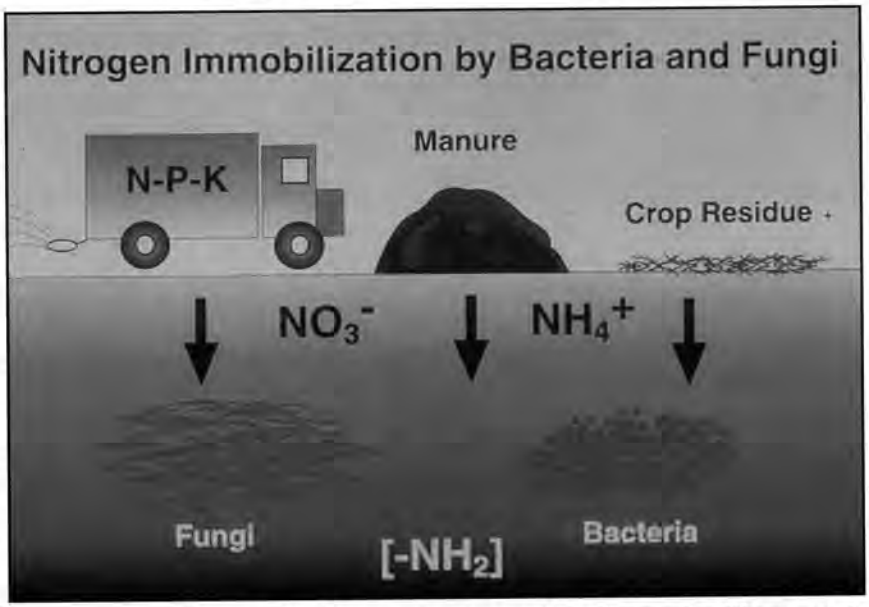
The **soil foodweb** is the intricate feeding interrelationship among the various macro and microorganisms in the plant rhizosphere (root zone) and surrounding soil mass. Microbes consume organic residues -- both decaying plant and animal matter and exuded carbohydrates from root surfaces -- extract mineral elements from clay and silt particles, and devour each other. They excrete waste materials through vacuoles or digestive systems, which wastes are taken up by other microbes or by plant roots. It is truly a jungle down there in the dark recesses of the soil.

The soil foodweb is important because crop productivity increases as the complexity of the organisms and their interactions increases. In order to maximize the yields of crops -- grains, vegetables, herbs, fruits, nuts, forages, grasses, and flowers -- we need to manage soil organisms to our best advantage.

Nitrogen Management

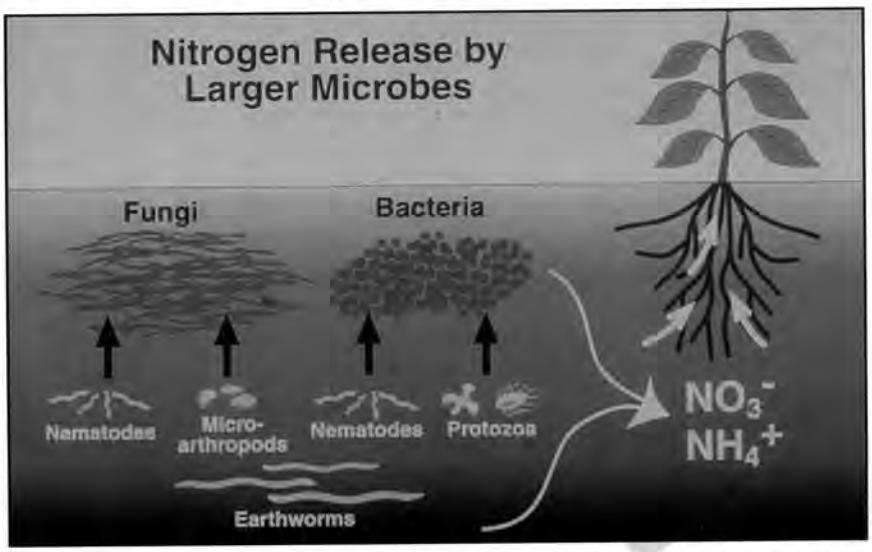
One of the most basic understandings of the soil foodweb is the means by which nitrogen is captured and released. According to Elaine Ingham in "What Do Different Plants Need?" (www.soilfoodweb.com), ***The interaction of bacteria and their predators (such as protozoa and bacterial-feeding nematodes), or fungi and their predators (such as fungal-feeding nematodes and microarthropods) produce as much as 80% of the plant-available nitrogen in the soil.*** That is a profound statement, one that is overlooked by most soil scientists and agronomists throughout the world.

The scenario of nitrogen cycling in the soil can be grasped in the two accompanying pictures. Notice that when nitrogen is applied to the soil as commercial N-P-K fertilizer, manure, or crop residues the soil fungi and bacteria immediately immobilize it: they incorporate it into their cellular structure [$-NH_2$], since they



desperately require this oftentimes limiting nutrient. Of course, plants need nitrogen as well, but are less vigorous competitors for it than are microbes.

Once incorporated into bacteria and fungi, the next tier of organisms -- protozoa and microarthropods, bacterial and fungal feeding



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15-Minute Soils Course

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nematodes, and earthworms -- attack the bacteria and fungi. They excrete nitrogenous compounds, such as urea and ammonia, that are readily available for plant root uptake. Thus, we see a beautiful system whereby nitrogen is quickly immobilized by soil organisms, and slowly released to plants as needed during growth. Because the bacteria and fungi tightly bind the nitrogen until it is released through predation, leaching, volatilization (evaporation), or denitrification (changing to nitrogen gases) are largely prevented. Effects of these organisms on other nutrients such as phosphorous, potassium, calcium, sulfur, and micronutrients are similar, but nitrogen affects are especially important because it is hard to manage.

1. **Disease-causing organisms are suppressed.** They are outcompeted by the beneficials.
2. **Aggregation of the soil is improved**, aiding in root penetration and air and water movement.
3. **Decomposition of plant and animal residues is promoted.**

Other Major Benefits of a Complex Foodweb

By having a complex array of small organisms (bacteria, fungi, algae, and actinomycetes) and larger organisms (protozoa, microarthropods, nematodes, and earthworms), other major benefits result:

Especially benefited by the many organisms of the foodweb is soil structure (point 2 above). Note the following analogy to building a brick house by Dr. Ingham:

Bricks: Bacteria glue the clay, silt, and sand particles into microaggregates.

Walls: Fungal hyphae, root hairs, and roots bind microaggregate clusters together.

Rooms: Arthropods, insects, and earthworms help bind together the clusters into "peds".

All of the organisms must be present to do the job right. Remember: as the complexity of the organisms and their interactions increase, so does crop productivity. Proper soil mineral balance and organic matter additions, plus good management practices, are essential for the system to work properly as well.

All of the practices used in crop production should encourage a vibrant and diverse array of soil organisms. Only then can the soil be defined as truly fertile.

See How Much You Learned

1. The complex interplay of soil organism interrelationships is known as the _____ _____.

2. Crop productivity increases when the complexity of the soil foodweb...
   a. Increases
   b. Stays the same
   c. Decreases

3. Nitrogen is immobilized in the soil by _____ and _____.

4. Which of these organisms are responsible for the release of nitrogen to plants?
   a. Protozoa
   b. Microarthropods
   c. Bacterial-feeding nematodes
   d. Fungal-feeding nematodes
   e. All of the above

5. Organisms feeding on bacteria and fungi release as much as 80% of the nitrogen required by plants. T or F

6. Soil structure is greatly benefitted by soil foodweb activities. T or F

7. Plant _____ can be suppressed by foodweb organisms through competition by beneficial organisms.

1. soil foodweb; 2. a; 3. bacteria, fungi; 4. e; 5. T; 6. T; 7. diseases or pathogens.

Compaction: Crops' Nemesis

Continued from page 3

fairly compact, roots will extend too slowly during the nine weeks of rapid growth to make it very far into the subsoil. The roots of corn under compaction may grow only 10 days into the subsoil to intercept water and nutrients, far too short a time to yield a maximum crop. Under loose soil conditions roots will go down eight feet, picking up water continually as they move.

Animals also compact soils with their hooves. A pressure of 15 to 20 pounds/in^2 is common under an animal hoof. Thus, it is possible for draft animals to compact the soil if there is enough traffic and minimal biological activity. Herds of caribou have compacted grazing areas over time, but fortunately cattle, sheep, and other animals oftentimes travel in pathways, much like controlled lane traffic for his recommended tillage system. Areas in Poland have been compacted in decades past from animal-drawn plows.

Fields that once were abandoned due to low productivity have been recultivated after 20 years, and produced excellent yields. While organic matter and mineral accumulations may account for part of this improvement, a reduction of compaction is a major reason for the change.

Tractor tires are serious compactors of soil no matter what the size, since they flatten out as the tractor moves.

Tractor tires are serious compactors of soil no matter what the size, since they flatten out as the tractor moves. The key? Drive a little as possible on soil with wheeled vehicles, especially when they are wet. Moisture reduces the bearing weight of structural units and allows them to crush, reducing macropores and greatly restricting oxygen movement.

Albert Trouse has done a lot to advance our understanding of soil compaction and root growth. We will do well to heed his research and recommendations for our own and our country's welfare. ■

To Desert in 35 Years!

Continued from page 1

aim of the colonists is to live at the same standard as the people of the motherland, or rather to live at a higher standard, justifying their emigration by surpassing the stay-at-homes in material prosperity. Thus almost as soon as they settle on their virgin soil, they begin not only to farm it, to exploit the soil fertility stores of centuries, but to build at once factories, railways, public utilities, and cities, and very soon to write and print books, paint pictures, build and man opera houses, theatres and bourses; in short, they try to establish *at once* the outward signs of a wealth which, in the "normal" way, would be the accumulation of centuries of toil upon the land.... But the consideration sent abroad from Oklahoma and similar North American soils in payment for the materials of high civilization *was soil fertility.*

Today it would probably be possible to turn the soil fertility of an area as large as the Dust Bowl into some other form of wealth, or into cash, in about ten years, with the aid of the enormously powerful machinery now available for soil-fertility mining. It would probable take no longer than that to turn semi-arid steppe, subject to drought, into a desert, and to possess in exchange a few cities, a few hospitals, a research institute, a few art galleries and theatres, some libraries, half a hundred factories, a score or two of rich men, and population of depressed proletarians. Fifty years ago the process, although far too rapid for the welfare of the soil, was not quite so fast. The Oklahomans, who presumably supposed that they were founding farms which would have the longevity of those of Europe, could anticipate, had they but known it, at least on the most easily ploughed and readily yielding of their soils, only *one generation* before those soils died beneath their feet and left them in the hideous predicament of the protagonists in Mr. John Steinbeck's *The Grapes of Wrath*.

The very rapid development of Oklahoma into a country with all the appurtenances of an old European state would not have been possible without the aid of capitalism, with credit bank-

See Credit Banking, page 7

Every so often we hear of a group of people who unite under extreme pressure to achieve seemingly miraculous results. In these moments human beings transcend their personal limitations and realize a collective synergy with results that far surpass expectations based on past performance. Anyone hearing a fine symphonic ... group hopes for one of those "special" concerts that uplift both the audience and the performers. Perhaps less frequent, but more spectacular, are examples in sports, such as the 1980 U.S. Olympic Hockey Team, a group of talented amateurs who stunned the world by winning the gold medal against the vastly more talented and experienced professional Russian and Finnish teams. These occurrences, although unusual, are much more frequent in American business than is commonly suspected.

William Rowe, Journal of Scientific Exploration, 12:569, 1998.

Oklahoma: Death of a Soil

Continued from page 6

ing. Europe did not have to stand the strain of this device until at least 600 years from the beginnings of her native culture. But the Oklahomans were able not merely to sell their soil fertility out of the State as fast as they could sow and reap; they could also make large drafts on their future activities as farmers, anticipating what they supposed to be the inexhaustible fertility of their soil by borrowing money at interest. And the bankers' interest was paid out of soil fertility.

The men of European culture and with European techniques who exploited the grass soils of the region which has since become known as the Dust Bowl, naturally applied to those soils the methods they knew and understood and which had answered so well in Europe for centuries. It seemed to them that they were in a peasant's paradise, for the soils were rich in plant foods, and had the appearance and texture of the best agricultural soils. But Northwest European rainfall is hardly anywhere less than 20 inches a year and in most parts nearer 40 inches. The soils of the Middle West had a mean rainfall of nearer 10 inches a year, and it was their grass cover alone which enabled them to maintain their stability during thousands of years in such arid conditions. Every drop of water was absorbed and held in the vast sponge of the grass-roots. But once ploughed the soil had no means of retaining water. In years of subnormal rainfall, the crops simply perished: in other years they might flourish by virtue of unremitting cultivation which conserved some water about the roots by means of a dust-mulch....

But in Oklahoma not only were artificial fertilizers made available to the farmer a decade or so after the settlement of that state, but monoculture very rapidly became the common-place of the region, a monoculture which was perfectly in accord with the American trend towards a thorough industrial specialization in all walks of life.

Moreover, less than twenty years from the land-rush of 1889, American farmers were offered an unprecedented opportunity to enrich themselves, or at least their bankers, by exporting American soil fertility in vast quantities to feed Europeans.

Less than 35 years after the settlement of Oklahoma, on a day of high wind from the west, a strange dark cloud hung over the city of New York and all the coast north and south of it. The phenomenon was to be repeated, but on this first occasion of its occurrence its novelty helped to impress the ten or twelve millions of people who saw it hang like a red veil over land and sea with its portentous, threatening, warning quality. The cloud was dust, and the dust was the topsoil of the Middle West, including vast areas of Oklahoma, on its way to be lost in the Atlantic. A combination of monoculture, dust-mulching, and a couple drought years in succession and a couple of weeks' high wind, had had its inevitable result. The soil of the Middle West was blowing into the Atlantic at a rate which, combined with water-erosion in other parts, could reduce North America to a barren Sahara in a matter of about a century.... ■

Control of the Packing and Milling of Basic Foodstuffs in the United States

Product	*Top four firms*	*Market share*
Chicken	Tyson, ConAgra, GoldKist, Purdue Farms	46%
Beef	IBP, ConAgra, Cargill, Beef America	72%
Pork	IBP, ConAgra, Cargill, Sara Lee	45%
Sheep	ConAgra, Superior, High Country, Denver Lamb	70%
Turkey	ConAgra, Rocco Turkeys, Hormel, Carolina Turkeys	35%
Flour milling	ConAgra, ADM, Cargill, General Mills	71%
Soybean crushing	ADM, Cargill, Bunge, ConAgra	76%
Dry corn milling	Bunge, Illinois Cereal Grains, ADM, ConAgra	57%
Wet corn milling	ADM, Cargill, Tate & Lyle, CPC	74%

[Dr. William Heffernan, Department of Rural Sociology, University of Missouri]

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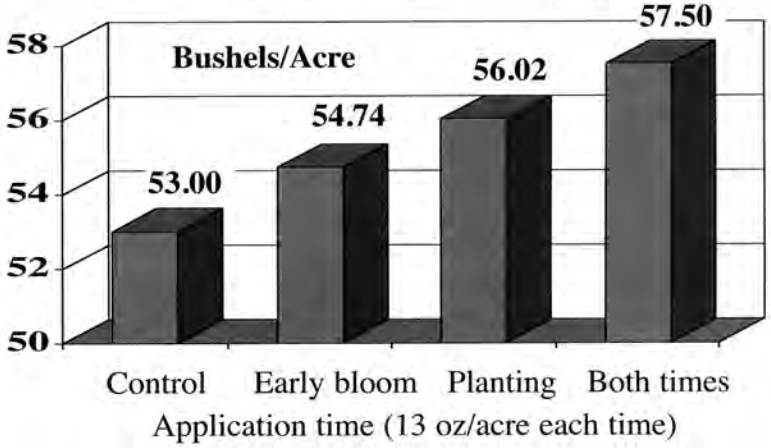

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