VERTICAL FARMING

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VERTICAL FARMING

PART I

The Origin and Character of Soils

Soils Are Rock Waste.—Soils were not originally a part of the earth's surface, but have been formed slowly by the crumbling and breaking up of the surface rocks into fine particles, such as clay and sand. Sometimes this breaking up occurred where the soils are now found, and the character of the soil is governed by the kind of rock that was left on the surface, while in other cases the rocks and the soil that came from them have been carried thousands of miles and mixed with other material, forming a conglomerate mixture from many sources. The highland and mountain soils in this country have, as a rule, been formed very near the places where they are now found, while the soils in the larger valleys, and along most of the coast line, have resulted from material washed down from the hills and deposited along the level stretches near the sea. Much of the soil of the more northern states has been brought down from Canada by the movement of ice along the surface.

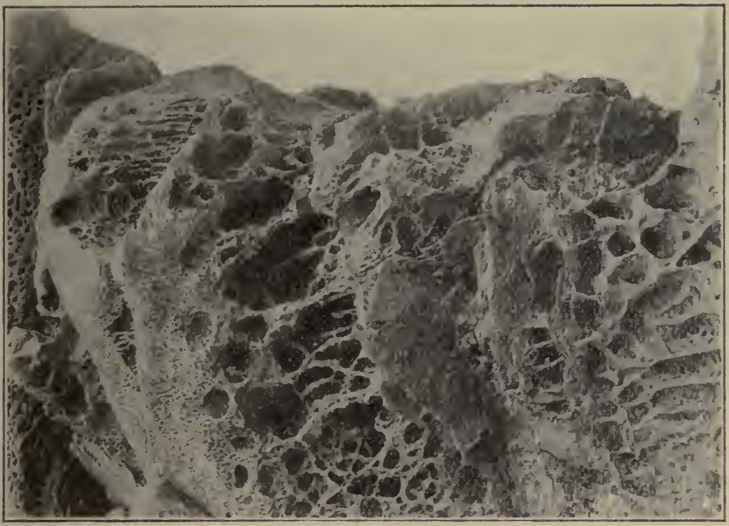
This breaking down of the rocks and formation and moving of the soil has taken a long time; but this work is yet going on, and the exposed rocks, boulders and ledges in our fields and mountains are yearly being attacked by the different forces, and are slowly yielding up material to help replenish the older soil. Different natural and artificial processes are also going on in the soils that may either improve or injure them. Most of these processes can be controlled by man and made to be his servant, so that he can become a great factor in the formation of profitable soil.

The breaking down of the original rocks has been accomplished by very simple means, the action of which has been very powerful.

Work of the Atmosphere.—Everyone knows how a piece of iron is attacked and falls into a powdery iron dust, which is nothing but iron combined with oxygen taken from the air to form a different substance called iron oxide. The oxygen, carbon dioxide and other gases of the air attack the iron, lime and other elements in the rocks, forming new substances and causing the particles to fall apart, as is the case of the iron

U. S. G.S. EFFECT OF WIND ACTION ON ROCKS

rusting. Rocks are also carved, eroded and worn away by the cutting and sawing action of the wind, especially when it carries with it any considerable amount of dust or sharp sand particles. In this way large rocks are sometimes entirely worn away. In some localities in this country the sand is swept across the level stretches so severely as to smooth off the rough places on brick walls, and to scar the glass in windows.



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LIME STONE AFTER EROSION

The Part Played by Water.—Much rock material is slowly dissolved out and carried away by rain water. This is usually carried long distances before being thrown back into a solid state by the evaporation of the water, or by coming into contact with some other substance that causes it to be precipitated. Often this reforms into another rock that may be harder than the original one.

A much greater effect of water, however, is in the formation of ice, which expands and acts as a powerful wedge in splitting off small fragments. You will often notice along the foot of a cliff, or at the base of a large rock, a mass of small splinters of stone that have been pried off the parent rock in this way. Running water also slowly wears away even the hardest rocks, reducing their close material into finer particles.

ENTRANCE TO THE GARDEN OF THE GODS
A BEAUTIFUL EXAMPLE OF EROSION

RUNNING WATER SLOWLY WEARING AWAY HARD ROCK

Glaciation.—During the glacial age vast sheets of ice, carrying with them boulders and everything else that was movable, passed over much of the United States and Canada, and ground

BOULDERS WORN SMOOTH BY GLACIAL ACTION

up the rocks into soil. Large areas of the richest soils were formed in this way. Smaller movements of ice occurred in the valleys of the Northwest and resulted in the formation of some wonderful soil areas there. These movements of ice leveled down the rough surfaces of mountain ranges and scoured out wide valleys.

Variations of Heat and Cold.—The variations of temperature from day to night and from summer to winter have also been busy in grinding out soil meal. When it is warm the rocks expand slowly, and contract under lower temperatures. The different minerals in the rocks expand and contract unequally, causing cracking which flakes off the outside of the rock and permits of its being attacked much more easily by other agents of destruction, or perhaps, better said, of creation. The effect of these changes of temperature are more noticed in some of the higher and drier regions where the hot evening gives way quickly to cold night. It has been reported that this action is at times so violent as to split large pebbles in half so quickly that a noticeable report, like the bursting of a percussion cap, is made.

ROOTS OF TREE WIDENING A CRACK IN A ROCK. WHEN GIVEN FISSURES TO GROW THROUGH ROOTS WILL PENETRATE HARD MATERIAL TO GREAT DEPTHS

Plants Render Assistance.—Just as soon as a little powder is formed from the rocks by the action of these agencies, minute plants, some of which can be seen only by means of a microscope, fasten on the rock meal and begin to grow. As they mature and die, their tiny bodies add the first organic matter to the newly formed soil and help prepare it for larger and more vigorous plants. The study of this action is very interesting, and a short search into any stony place will reveal many examples. Mats of short moss will be found growing on what seem absolutely dead and impervious stone. Trees can be found sending their roots into the smallest fissures in the rocks and bursting them wider. It is a hard life for these plants, and their growth is slow and stunted, but it is one of their missions in nature and they go on with the heavy work, giving to man at the same time a wonderful revelation of what he can accomplish in the way of improvement by giving cultivated trees and smaller plants a suitable place to grow, rather than force them to combat all the adversities of a resistant soil.

Animals Help.—Tiny worms and bugs soon begin to burrow into the weaker points of the rocks, and as the work goes on much larger cousins follow them. Their action is to open channels through which water can reach more effectively the harder rock within. They also do large amounts of grinding and mixing on their own part. Their excretions and their dead bodies add more organic matter to the soil and help pave the way for a good garden or a fruitful field.

U. S. G. S.

SOIL GROUND AND MIXED BY ANTS

Each Force Helps the Others.—These forces in their slow work of grinding up the rocks into earth meal do not work separately, but each helps the other. When one worker has opened a way into the rock, his success is immediately followed by activities on the part of the others. The roots and worms open channels to permit the entrance of more water, which may mean more freezing and more cracking, and there is more room for roots. An expansion crack works the same way. The pits made in the face of the rock by the action of the air make suitable homes for the mosses and other plants. It is a big job, and the work is accomplished only by all hands keeping busy.

The Formation of Humus.—The rock powder or meal does not of itself make a desirable soil, and other matter must be added. Microscopic plants must flourish to help in the work of crop production; water must be present, and as a rule, the more humus the better the crops. This humus is not a strange sort of stuff at all, as it is only rotten trash from dead plants or animals. Mention has already been made of how its first start is made. This is later augmented by the growth of larger plants which have more leaves, twigs and roots to rot. In increasing the amount of humus in a soil the work of man, when intelligently applied, can be made to do wonders.

GREEN MANURE CROP FOR INCREASING HUMUS

How Soils are Moved.—After the agencies just described have ground out the rock powder, nature keeps right on at work in moving and sorting out the soil particles. This work is done by the action of:

Gravity.—The soils formed on the mountains and cliffs fall to the base forming a heap of debris which is called "tallus." Where the slope is steep, this falling is immediate; but where the land is more level, the movement is slower and is more of a slide than a fall. Gravity is ever at work moving soils from high to low levels.

U.S.G.S.

THE MOVEMENT OF SOIL FORMING MATERIAL BY GRAVITY.

Water.—Every drop of water that falls on the earth can move a particle of soil at least a little distance. These drops of rain run together to form rivulets, each with its little load of soil. Rivulets meet to form streams, and these join to form creeks, and the creeks unite to form rivers. A creek or river in flood-time is a stream of soil moving down from the factory to be spread out over distant valleys and plains, or to fill up the bottom of the sea so that it can finally be used by man to grow food and raiment.

Glaciers.—The great sheets of ice that have already been described moved great distances, and carried with them large amounts of soil and soil material. Some of them moved from Canada into what is now the United States, and brought fertile material far within our borders to make some of the richest land in the world.

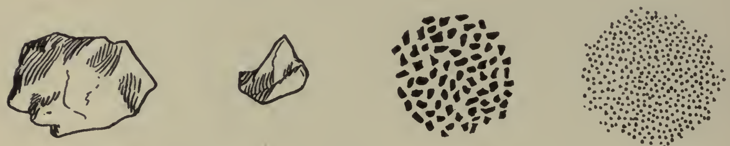
Winds.—The housekeeper knows how fast dust accumulates over everything, and how it thickens on furniture and carpets if left undisturbed for even a short time. The winds

AN ALPINE GLACIER GRINDING "SOIL MEAL" AND MOVING IT FAR FROM ITS PARENT ROCK have been busy, not for days but for centuries untold, picking up soils in one place and dropping them in another—sorting and arranging them until it is probable that any given section of land anywhere contains particles contributed by every other section in that district.

Residual Soils.—Not all soils are moved in these ways. In places, sometimes large, sometimes small, the original rocks of the locality have weathered down into soils that remain just where they were formed. These are known as "residual soils," and embrace a great variety, some of which are fertile, while others are not so well favored. The proportion of residual soils to transported soils varies greatly in the different parts of the world.

Some of the Physical Characteristics of Soils.—Soils have a number of marked physical characteristics, some of which are of interest only to the exact scientist, but many of these characteristics are of the greatest interest to the poorest farmer. The greatest advances made in the Science of the New Agriculture have been due to the study of these physical characteristics of soils, and the application of the discoveries along this line have tended toward a better and more profitable agriculture.

Soil Texture.—One of the most noticeable differences in soils is the variations in the size of the grains of rock powder of which they are made. The fineness of a soil is spoken of as its "texture." The sizes of grains most discussed and best understood both by the student and farmer are: clay, silt, sand, and gravel. It is well known that sand, loam, and clay soils will not raise the same crops equally well. There are good reasons for this. In a sandy soil the particles are relatively large and do not pack so closely together. No matter how tightly packed a soil may be, there are always small openings and cavities between the particles. These are called "pores." The sandy soils do not pack so closely together as do the clays, and the pores are therefore larger and permit a much easier movement of water and air in the soil. The clay soils pack more closely together and reduce the size of the pores so that both the water and air move more slowly. The silts and loams are intermediate between the sands and the clays. Loam soils are made up of mixtures of fine and coarse soil particles. If the loam carries a large percentage of sand it is known as a sandy loam; if the clay particles predominate in amount, it is known as a clay loam. The presence of gravel among the other particles materially affects the texture of a soil and often the fertility as well. When a considerable amount of these particles are present in a loam soil it is usually called a gravelly loam, the difference in clay and sand being maintained as before. The intermediate textures, such as fine sandy loam, silt loam, and the lighter clay loams are usually considered the best, as they tend to be light, well drained and easily cultivated.



COMPARATIVE SIZES OF SAND AND CLAY PARTICLES (ENLARGED)

When the percentage of fine gravel and coarse sand is high, the soil is likely to be too loose, too easily drained, and not likely to withstand drought well. Such a soil, especially in the rainy regions, is likely to be deficient in one or more of the chemical elements needed for the production of plants. Where the percentage of fine silt and clay is high, the soil is likely to be cold, heavy, and sour. Such a soil, unless well tilled to considerable depths, resists the ready movement of air and moisture.

Soil Structure.—Another important physical characteristic of soils is the way the particles arrange themselves as they lie in the field. A coarse sand is found to have every particle lying separate, and alone with no attachment to the particles which it touches, unless they are cemented together by excesses of lime or similar substances. The clay in a path will be found to have its particles arranged in much the same way as the sand, with the important exception that each is pressed close to its neighbor and bound there by cohesion, by adhesion, by some other substance present, by interlocking corners of the particles, or by other means. When such a soil is disturbed it does not fall apart like sand, but remains in close, hard lumps or clods. In these soils we have the extremes of structure—the open structure, or the individual grain and the dense structure or arrangement of the pubbled soil. A well-tilled plat of clay or loam will be found to have an entirely different structure. Here the fine particles of clay, silt and sand are bound together in little groups or crumbs. These crumbs or granules can be easily detected by picking up a handful of the soil and gently breaking it apart. These crumbs lie close against other crumbs, but unless poorly handled in cultivating they do not become sealed together. This is the ideal structure of a soil, and it is toward the formation of such granules that we should direct our attention, especially in the heavier soils. When such a soil is cultivated wet, the pressing action of the plow or harrow tends to force the particles closer together and to form the undesired puddled structure; but if the moisture content is just right, the same plowing will tend to make the granulation still better. Additions of humus material, and, on some soils, of lime, help also.

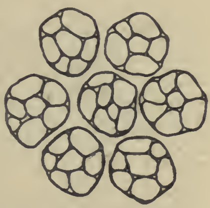
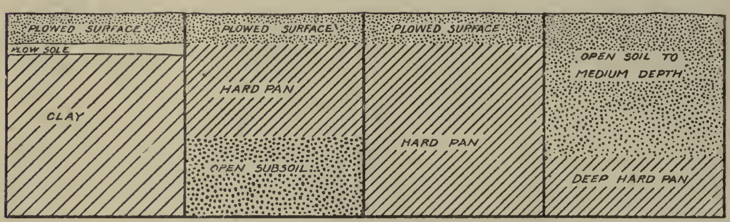


DIAGRAM OF SOIL GRANULES

Such a crumb structure in a soil brings about most of the benefits and advantages of both a sand and a clay. It drains well, and because of its open structure warms up well in the spring. The openness permits easy and good plowing. The fine particles absorb and hold the large amount of water needed for the crop, and if properly cultivated to preserve this moisture, will tide heavy crops over longer periods of rainless times. Another great advantage of the crumb or open structure of clay and loam soils is that they allow the roots to grow quickly to great depths. This affords the plant a much larger amount of soil from which to draw moisture and food, and consequently yields heavier crops. In another paper the good effects of this open structure on beneficial bacteria will be pointed out.

Hardpan and Plow Soil.—Another soil structure that needs attention is hardpan. Sometimes this is simply the tight puddled clay that has already been described; and sometimes it is clay, silt or sand that has been cemented together by some chemical or mineral substance in the soil, or by the soil particles themselves being so tightly pressed together that they prevent the movement of water and air, and retard the growth of roots. One kind of hardpan is called plow sole, and is found just at the bottom of the plowed furrow where the slide of the plow has been for years packing down the soil just where it needs to



COMMON TYPES OF HARDPAN

be opened. The relief from such conditions is found in deep cultivation that will crack the material to pieces and permit good drainage where it is bad. This breaking must, of course, be deep enough to reach the seat of the trouble. Any adverse conditions, such as an excess of alkali or a lack of lime, should be immediately corrected.

Soils and Subsoils.—By soil we mean the surface as contrasted with the lower stratum of subsoil. Ordinarily they have come from the same source, and at times are so much alike that it is hard to distinguish between them. This is particularly true in the semi-arid regions, and in the deep aluvial belts. Usually there is a difference in texture, structure, and color. The soil has been well weathered and has undergone changes that will permit the giving up of its mineral plant foods to the roots of plants. These changes have gone on more slowly in the stiffer subsoils, and much of the mineral substances have not been acted upon sufficiently by the air and by bacteria to give up the needed foods. Deep cultivation and the use of explosives open up these soils to the action of the air and other agencies so that these foods may be prepared for the roots, and increased fertility and greater returns in crops are the result.

Soil Areas, Series, and Names.—The soils of the United States are classified into thirteen subdivisions called "Soil Provinces," or regions, according to the essential geographic features, such as the Atlantic and Gulf Coastal Plains Province, the Appalachian Mountain and Plateau Province, the Great Plains Region, the Arid Southwest Region, and the Pacific Coast Region. The soils of a province are classified in soil series. The soils in a series have the same range of color, same general character of subsoil, a common or similar origin, about the same structure, and broadly, the same type of relief and drainage. The soil series are divided into individual soils, which generally receive local names, as: Portsmouth Sandy Loam, which is found in several states from Delaware to Mississippi; Vermont Silt Loam, of Kansas and Texas; and the San Joaquin Fine Sandy Loam, of the Pacific Region. A soil class includes all the soils having the same texture, and are called: sands, loams, clays, fine sandy loams, clay loams, clay loam adobe, or such other combination of descriptive words as best fits the peculiarity of the soil.

Maps of the soil surveys of the various provinces, and descriptions of the series and individual soils of the surveyed areas will be found in the annual reports of the U. S. Bureau of Soils, and may be consulted at the larger public libraries; or if a particular county has been mapped, the report on it can be gotten from the U. S. Department of Agriculture.

Chemistry of the Soil.—While it is true that the productiveness of a soil depends more on its physical character and condition than upon its chemical composition, yet the chemical elements are of great importance and must be taken into consideration. Many chemical elements are needed for the production of a plant, but it is seldom, with the exception of potash, lime, phosphorus, or nitrogen, that any of these is not present in sufficient amounts. All of these except the last named occur in many rocks, and are therefore found in the soils in varying amounts. When, on a particular soil, one or more of these is absent or deficient, it is necessary to add it in some form of fertilizer or manure.

The soil particles may not be weathered enough to make these minerals available, or there may be little in the surface soil and more in the subsoil. In either case the soil is improved and the plant food brought within the reach of the crop by breaking and stirring up the land with explosives.

Fertilization and Chemical Correction.—In addition to the proper physical condition, it is necessary to have the chemical condition of a soil well regulated in order that we may get the proper returns from our labor. Some foods may need to be added to the soil, or it may be essential that a harmful substance be removed or neutralized. This work will be considered in a following chapter.

QUESTIONS

1. Describe the formation of one type of soil not made from rock particles.

2. Does the action of the air always soften freshly exposed rocks?

3. Name the forces that have been most effective in forming the soils in your vicinity.

4. By what agencies have your soils been moved?

5. Is the typical soil of your farm finer or coarser than the underlying subsoil?

6. Can a mixture of coarse sand and clay become as tightly compacted as a dense clay?

7. What, in detail, are the processes in the formation of plow sole on your typical soils?

8. Why are arid soils less troubled with shortages of plant food than humid soils?

9. What physical characteristic of your soils lends itself most readily to improvement?

THE RESULT OF GOOD DRAINAGE, GOOD AERATION AND PLENTY OF PLANT FOOD

VERTICAL FARMING

PART II

Fertilizers and the Chemical Properties of the Soil

HOW PLANTS FEED

The fertility of a soil is its ability to produce crops. It is not one condition, or two or three conditions, but the sum of all conditions. It does not consist simply in hauling manures or buying chemicals. It means that the water, air, temperature, soil bacteria, tilth, and plant food or soil solution exist in the right conditions and proper balance as well as in proper amount. It is possible for seed to sprout, the crop to grow and ripen, and the yield to be the best only when all these conditions are fulfilled. Mere richness in mineral foods avails nothing if water is lacking to maintain a large amount of soil solution for the roots to absorb. The plant food may be there but may not be soluble and cannot be absorbed. It may be soluble, but in a form distasteful to and therefore rejected by the roots.

All soils, even those considered poor, contain vast amounts of plant food that is not naturally available, but which can be converted into an available form. In such a case the problem is one of condition and not one of total content. A worn out soil is often only an unsanitary one and can be rebuilt to a high state of productivity by proper cultural methods.

Chemical Properties of the Soil.—While hundreds of minerals are known to science, only a few are used in nature in forming the common rock from which most soils are derived. The more important of these to the farmer are potash, phosphorus, and lime, as these are at times deficient or else appear to be deficient. Such elements as iron, aluminum, and silica may be ignored, as they are nearly always present in sufficient quantity to more than supply any demand made on them.

For most agricultural conditions it is almost imperative that the soil be not acid. The chief corrective for a sour condition is lime, which is usually present in sufficient amounts for a food, but in many soils is needed to overcome the sour conditions produced by vegetable decay or bad drainage. It may be added in several different forms. At present, carbonate of lime or finely ground limestone or marble dust is largely used for this purpose. This form is preferred by many on account of there being no danger of trouble from an over-application. Hydrated lime is also largely used, as is rock or quick lime. In

Courtesy Charles Warner Co.

MAMMOTH LIME KILN

using the last named form, care must be exercised to prevent a heavy application from burning the organic matter or humus out of the soil. Ground or burned sea shells are also extensively used and make an excellent form of agricultural lime. Gypsum is used under certain conditions. Lime also has a material effect on the structure of the soil, especially when it has a tendency to be sour, by causing it to granulate better, thereby increasing its power to absorb and hold water. Especially in the east and southeast the use of lime is imperative for the best success in growing alfalfa and certain other legumes. The cow pea seems to resist a sour condition in the soil remarkably well. Lime also helps somewhat to liberate potash from resistant minerals. Salt is sometimes used for the same purpose. The growth of nitrogen fixing bacteria is greatly stimulated when lime is added to make up any deficiency that may exist in the natural soil.

Potash is a highly essential plant food. It exists naturally in most soils and in some of them is found in large amounts. In some soils, notably coastal plains sands, it is present in but

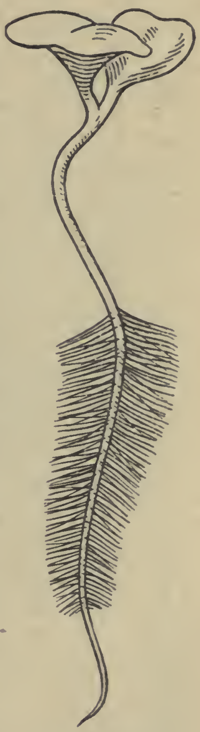
SHIP DISCHARGING CARGO OF EXPENSIVE FERTILIZERS small amounts and must be added artificially. Considerable amounts are found in natural manures, but the great supply is imported into this country from Germany.

Phosphorus is also present in most normal soils, but the percentage is small in some of the most valuable soil provinces of the country so that it must be added artificially. Large amounts of phosphate rock are mined in this country. The rock may be ground and added to the soil in the form of a fine powder, provided the soil has a good supply of organic matter. If this organic matter is deficient and the soils are thin, the best results are reported from the use of acid phosphate which is the phosphate rock after it has been treated with sulphuric acid. Large amounts of phosphorus are used in the form of slag and bone products. The United States is more than self-sustaining in the supply of phosphates and export large amounts annually.

Another of the important elements is nitrogen, which is found in the form of nitrates in some of the desert regions. In this form it is very soluble and is washed out of the soil by rains. It is found in normal agricultural soils in varying amounts, but is often in too small quantities. Commercially it is obtained from fish and packing house scrap, from cotton seed, from nitrate of soda imported from Chili, and from the air. Nitrogen is a gas and makes up the larger part of the air, from which it may be taken in large amounts by certain bacteria growing on the roots of legumes and by other microscopic plants working alone. Further mention will be made of this later.

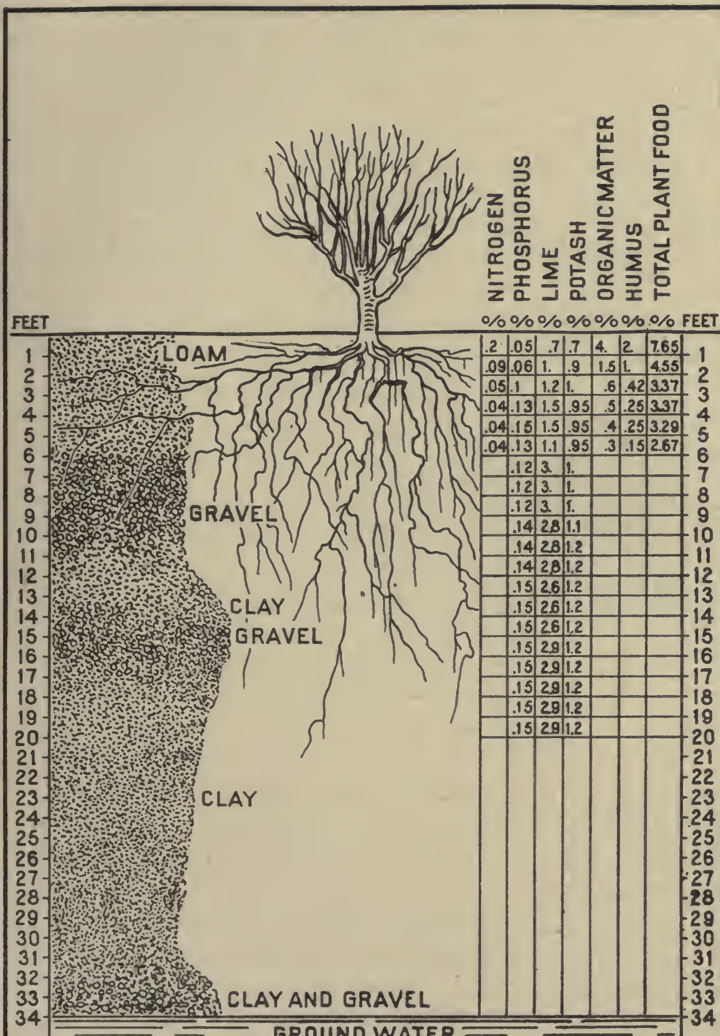
How Plants Feed.—Plants feed by absorption through the roots and by inhaling the air. When a plant is burned, most of its weight is lost in the form of gases and but a small part is left as ash. The ash contains the mineral matter which came originally from the breaking up of the soil minerals, or was added as a fertilizer. The rest, or the part that was lost in the gas is made up of carbon, hydrogen, oxygen, and nitrogen. The carbon is taken in through the leaves from the carbonic acid gas of the air. The hydrogen and the rest of the oxygen are taken in through the roots in the form of water, and the nitrogen is derived from the soil where it may have accumulated from artificial supplies, from the action of bacteria, or from the decay of organic matter. The relative amounts of these elements demanded by different plants varies considerably, as some require a large supply of one food element while others can grow well with much less of it.

Only the root hairs, the most delicate part of the root system, can absorb foods. These are tiny threads growing out from the roots just back of the tiny feelers or root tips that thrust themselves through the soil. The walls of these root hairs are very thin and absorb the soil solution direct as they lie in close touch with the soil particles covered with their thin coat of "Mineral Soup." These dissolved mineral foods then pass on into the circulating system of the plants as sap, and are carried up to the leaves. The sap in conjunction with the carbonic acid taken in by the leaves then forms the starch, sugar and similar compounds of the plant and the excess of water is lost through the leaves. The amount of water evaporated in this way is enormous. It has been found on experimentation that it requires from 200 to more than 600 pounds of water, passing through a plant in this way, to make one pound of dry crop. These large amounts of evaporated water show how necessary it is to keep the soil in such a condition that it will absorb the maximum amount of rainfall and hold it to supply the growing crop. It is also necessary that these tiny root hairs, that are so small that it would take 300 or more laid side by side to cover an inch in width, be able to creep and grow always deeper and further into the soil, unhindered by impacted soil, hardpan, or other obstructions.


ROOT HAIRS

The roots do not reach down to all of the water they use. Some of it is pumped up to them as oil rises in a lamp wick, by capillary action. This rise is much faster in well granulated soils than in hardpan or tight clay. It is evident, therefore, that no method of cultivation can reach down deep enough to overcome the difficulties of feeding roots except blasting the subsoil with explosives.

Unavailable Plant Foods.—Attention has already been called to the large amounts of mineral plant food bound up in insoluble minerals, and to the enormous amount of the highest priced plant food (nitrogen) that is present in the air but not directly available to the field crops as food. The changes that some of these must undergo in order that they can nourish the roots are chemically very complex, but, in the practice of the art of farming, can be well controlled. The nitrogen must be combined with oxygen. This change is most effectively brought about by a certain group of bacteria which grows in knots on the roots of peas, beans, clovers, alfalfa, and kindred plants. They breathe in the free nitrogen gas and combine it with other elements in such a way that large amounts are fixed and held in the soil in a combined form that is very nourishing to succeeding crops and also to the crop with which they grow. Other forms of organisms accomplish the same purpose, working without the assistance of the leguminous associates. Both forms require certain well defined conditions in which to work. Each of these is so essential that it would be hard to name the more important one. The soil must be well drained so that there is no clogging up of the soil pores with water, but at the same time the soil must be moist. The soils must also be warm, for the activities of these wonderful little farmers' aids are retarded if stopped by frost. Large supplies of air are equally essential. As most of these conditions attend a deep tilled soil, it might be said that the beneficial bacteria of the soil are all deep tillage enthusiasts. They are found at considerable depths in the porous types of soil, but cannot live much below the surface in tight clays and hardpan. They also keep busy on insoluble



FEET	NITROGEN %	PHOSPHORUS %	LIME %	POTASH %	ORGANIC MATTER %	HUMUS %	TOTAL PLANT FOOD %	FEET
1	.2	.05	.7	.7	4.	2.	7.65	1
2	.09	.06	1.	.9	1.5	1.	4.55	2
3	.05	.1	1.2	1.	.6	.42	3.37	3
4	.04	.13	1.5	.95	.5	.25	3.37	4
5	.04	.15	1.5	.95	.4	.25	3.29	5
6	.04	.13	1.1	.95	.3	.15	2.67	6
7		.12	3.	1.				7
8		.12	3.	1.				8
9		.12	3.	1.				9
10		.14	2.8	1.1				10
11		.14	2.8	1.2				11
12		.14	2.8	1.2				12
13		.15	2.6	1.2				13
14		.15	2.6	1.2				14
15		.15	2.6	1.2				15
16		.15	2.9	1.2				16
17		.15	2.9	1.2				17
18		.15	2.9	1.2				18
19		.15	2.9	1.2				19
20		.15	2.9	1.2				20
21								21
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33								33
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THE DEEPER PLANT FOOD MIGHT JUST AS WELL BE IN EUROPE FOR ALL THE ATTENTION THAT IS USUALLY GIVEN IT forms of combined nitrogen that may be added to the soil, and convert it into usable forms.

Soil changes also materially affect the availability of phosphate material. In nature it is always combined in slowly soluble compounds. In commercial fertilizers it is usually combined with lime. Different relations in the amount of lime to the phosphorus effect the solubility of the phosphorus. In badly drained land the phosphorus is often found combined with iron in little balls of "bog ore" that are very insoluble. Many other examples of combinations of plant foods could be brought out going further to show how the air, water and bacteria assist the changes. In every case the benefits brought about demand deep stirring of the soil, such as is produced by exploding small charges of slow powders in the subsoil and opening a way for the liberators of plant food. No other practical method can bring about the desired results.

Deficient Plant Food.—If the rocks from which a soil is derived are deficient in any needed food, it becomes imperative sooner or later to add some material that will make up the deficiency. The original and best general fertilizing material is manure, as it adds not only certain amounts of plant food, but also large amounts of humus. Forest mould, litter, straw, and other materials of like nature add some of the fertilizing elements and also humus. The number of materials that may be used to add plant food is great. Some materials carry but one needed element, while others carry two or three. There can be no general rule promulgated to guide in choosing fertilizers, as different soils and different crops demand certain chemicals in different forms.

Soil Amendment or Correction.—Some soils well supplied with mineral and organic plant foods have some trouble, such as sourness or an excess of alkali. Materials not classed as foods are used in the correction of such conditions. These materials are generally known as "Soil Amendments." In the correction of black alkali, gypsum is added to change the sodium carbonate to a less harmful compound which can more readily be leached out.

The other great amendment is lime, the chief use of which has been described in the correction of sour or acid soils.

Use What You Already Have.—From the foregoing we see that there are supplies of practically all the plant foods in normal soils, and that additions of fertilizing materials, while absolutely essential in some cases, are expensive. Some of the foods already in the soil are not in the form needed by the plant, but can be changed into usable forms by properly controlled natural agencies. The agencies needed for these changes are always at their best under certain soil conditions. For the different changes the conditions are identical—a moist but well drained soil, an abundant supply of air in the soil, the presence of more or less humus, and a suitable temperature. To obtain most of these is easy, when we consider only the soil, as it can be done with a plow, but the surface is not half of the farm—we want to use several feet of depth for a good reservoir for moisture, a factory to rework and prepare the foods, and a good home for the roots. This naturally demands that the clay or hardpan be broken up. The plow cannot get down to the trouble and there is but one other agent that can do the work—a reliable low-freezing explosive.

SECTION BREATHING PORE OF A LEAF (GREATLY ENLARGED)

SURFACE VIEW OF SAME

Making Fertilizers More Effective.—Heavy applications of fertilizers to force bumper crops are attended with certain dangers. If everything goes along all right, and there is always plenty of moisture to dissolve the fertilizers and prevent the soil solution from becoming too rich, the desired results will in all probability follow. In most regions where such fertilization is practised, such constant supplies of soil moisture are not always to be relied upon. The result is that when the young plants get vigorously started on their nourishing ration and then meet a season of drouth they are "scorched" or "burned" by the too concentrated food, and are left in worse shape than if there had been no fertilization and they had been forced to draw all their food from the soil minerals.

Even where the conditions are normal rather than extreme, the increased growth caused by the fertilizer calls for a greater supply of moisture to support the enormous loss through evaporation from the leaves, and the fertilizer has in no way met the increased demand for the water. The correction for either condition is simply the prevention of excessive amounts of the water being lost by drainage and holding it stored in a deep tilled, open subsoil. A tight subsoil will not absorb and hold the moisture in this way and needs the welcome relief of a small amount of well placed explosive to shatter and open the soil, so that it can meet the demands for more water.

QUESTIONS

1. Name in full the conditions necessary for heavy yields of your money crop.

2. What fertilizing material is lacking in your soil, and in what form would you supply the deficiency?

3. Do the large brace and tap roots of plants absorb plant food from the soil? What is their duty?

4. Will a large tree draw most of its food from the ground immediately around the stump or from the soil further away?

5. What is the source of the most used chemical fertilizer in your community, and how is it prepared before being offered for sale?

6. What effect has lime on clover on your farm? On wheat? How can you prove your statement?

7. Which shows wilt first during a season of slight rainfall, a heavy or light crop? Why?

VERTICAL FARMING

PART III

Soil Moisture

ITS CONTROL AND CONSERVATION

Crops must have sufficient amounts of water at the right time. The greatest demand for water is often during the season of least supply. The water must come from the feeding zone of the roots within the soil. No phase of agriculture is of more importance or worthy of more study than how to maintain an adequate supply of soil moisture. A soil may be rich in plant food and not have water enough to dissolve it and carry it to the plant roots. Nothing reduces the fertility of the soil and the yields of farm crops in the United States annually more than the lack of a proper supply of water at the season when the crops demand it. The rainfall may be deficient or too unevenly distributed so that the farmer is forced to store water somewhere and in some way. There are few sections of the country where this is not necessary; where there is rain enough during the growing season to water the crops. They must draw their supplies from reservoirs that are above or below ground, and the best of all is utilizing the soil itself as a reservoir.

Soil Water as a Plant Food.—All vegetable matter consists largely of hydrogen and oxygen, which elements are obtained from the soil water and combined with other elements in the plant itself. These combinations of the water forming elements, together with a small amount of carbon from the air, form by far the greater weight of domestic plants even when they are thoroughly dried. It is the water used as food that makes up

GOOD TOP AND ROOTS POSSIBLE ONLY ON
A WELL DRAINED SOIL

the greater part of all the starch, sugar and other similar compounds so valuable, in that they form one of the essential parts of the foods for men and lower animals.

Water as a Carrier of Plant Food.—All of the plant foods in the soil have first to be dissolved in water and then carried by it to and through the roots and up to the above ground parts of the plant. The tiny feeding roots must be immersed in the thin film of water that clings to the soil particles. The soil solution is absorbed into the rootlets through their walls and forced upward with a considerable pressure. This can easily be noticed by cutting off a rank growing weed and watching how quickly the sap is thrown up over the newly cut stump. This pressure is often several pounds per square inch. All the water that is not combined in the plant as a part of it is thrown out through the leaves, this process being called "transpiration."

If the moisture conditions of the soil are good and water is abundant, transpiration is encouraged and there is an attending satisfactory growth of crop; but if the conditions are reversed, the plant growth is immediately stunted by the deficiency in the amount of the essential water.

Amounts Necessary for Crops.—Taking crops altogether, from rice to date palms, the amount of water required varies from complete submergence to almost perpetual drouth, and within this range crops vary widely as to the amount necessary for living. As a rule the amount is large, as it is only the desert plants that thrive on a scant supply. Take a small potted plant and place it under a glass jar and notice how soon the jar is clouded by the water vapor taken up from the soil and given off through the leaves. From 200 to 600 pounds of water are transpired by ordinary crops for every pound of dry matter produced, but this varies with each crop according to the climate and other factors affecting it.

A good yield of pea vine hay will draw 1200 to 1500 tons of water through its roots and stems and liberate it in the air. Corn and cane drew equally heavily upon the soil supply of moisture.

The water required by a field of any of the ordinary field crops, if spread over the surface, would cover it to a depth of several inches, sometimes as much as a foot or more. This is only the water used by the plant itself, and does not include the amount that is lost by being evaporated or that passing too deep into the soil to be drawn back to the roots. In addition, a plant cannot take all of the moisture out of the soil in the range of its roots. In irrigated districts the amount of water applied to and absorbed by the soil often reaches an amount equal to three feet, and in some localities more.

This water used by the plant or lost by evaporation from the soil during rainless days must all come from the soil, and shows what care must be exercised in storing and holding all that is possible.

Water and Soil Temperature.—A uniform soil temperature is essential to the best growth of crops, and a soil properly supplied with moisture will change its temperature very slowly, while a dry, parched soil will quickly heat up during the day and cool off again as rapidly at night, and the crops will suffer accordingly. Coarse soils retain only a relatively small amount of moisture and are warm and early. Fine soils, like the clays, retain much more water and are cooler and later in the spring.

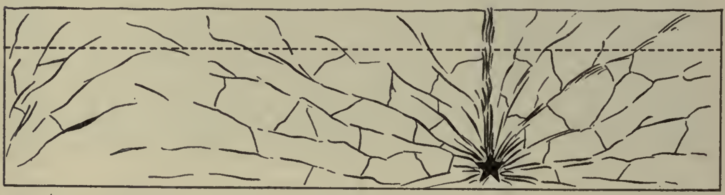
Storing Water.—Where irrigation is practised, reservoirs are used to store and hold water, but in most of the states this method is inadvisable. The best place to store the water for use in time of drouth is in the soil itself, by converting the subsoil of every acre into its own reservoir. This large storage may be assisted and encouraged in several ways. The first thing to do is to be sure to get the rain water down into the soil instead of allowing it to be wasted by running off on the surface, because it cannot enter a hard or impacted soil readily, if at all. Such soils may be found to be dry even after a heavy rain. In "dry farming," and also in farming where the rainfall is heavier, some practise rough plowing before the seasons of heavy rain to increase the absorption of rain water, and later harrow or drag the surface to form a mulch and prevent loss

U. S. Rec. Service

IRRIGATION DAM—THE EXPENSIVE METHOD OF STORING WATER FOR PLANTS

through evaporation. Where this practice has been carefully followed, good has resulted, but ordinarily the depth to which plowing is possible is insufficient to reach the zone of the greatest trouble. Others have gone further and plowed deeper, using heavy tractors with subsoil plows. The results obtained have been variable, and it is quite evident that the efforts along this line, while well conceived and of benefit, have fallen short of their mark by not disturbing the soil to a sufficient depth.

In most cases of resistant soils, the trouble is at a considerable depth, in fact, below the depth that could possibly be reached by any form of plow. For relief then, there is nothing practicable but a rational use of a subsoiling explosive. This, like the subsoil plow, is used when the subsoil is dry, so that the force of the explosion will shatter and pulverize the subsoil rather than pack it into a more impervious mass. Usually this is in the late summer and early fall, when the plants have pumped all of the available water out of the soil. This season is followed by the fall and the winter rains which can then find their way deep into the cracks and fissures where they are absorbed and held indefinitely if proper care is given to the surface. The heavy rains following such a shattering of the subsoil have the additional advantage of resettling any parts of the soil where the explosion may have opened it up too much. In the spring and summer following such a soil treatment, the young roots find an easy path into the deeper soil, where they can continue to draw their full ration of water from the stored supply and thus nourish the crop during long seasons of drouth.



SUBSOIL SHATTERED BY A BLAST—THE CHEAP WAY OF STORING WATER FOR PLANTS.

Excesses of Water Must be Drained Away.—Field plants will not grow in a soil saturated with water. An ample supply is necessary and must be maintained, but a great deal depends on how the supply is kept up, or in other words, on the moisture condition. Land animals require water to drink, but perish if immersed in it, for the air necessary for their existence is then shut off. Plant roots die if the soil is saturated with water because their air is cut off. Fortunately, soil will hold only a certain amount of moisture if the water is free to move, the excess gravitating downward and draining away. This is called gravity of free water. The gravity water sinks until met and checked by impervious material or reaches standing water; that is the water table. Unless such free water sinks too deep, it is not entirely lost to the plant, as it not only sinks through gravity, but is also brought back to higher levels, when the top soil begins to dry, by capillary attraction, just as water climbs up a piece of cloth, one end of which is allowed to hang in water. This capillary water is the water that supplies the immediate demands of the plant. Some of the water collects on the surface of each soil particle and sticks to it with a peculiar force, forming a film over the soil grain. This "Film Water" is very important, for the force that holds it so closely to the grains enables it to dissolve the mineral plant foods in the particle and prepare them for absorption by the roots.

Air Must Circulate in the Soil.—The air in the soil is as essential to plant growth as the air above the soil. This soil atmosphere below the surface is heavier than the air above, and contains more carbon dioxide and similar compounds than our atmosphere. These gases are absorbed into the soil water and become a part of the attacking force that liberates the mineral foods from the dense minerals. The nitrogen supply of the

CYPRESS ROOTS THROW UP "KNEES" THROUGH WHICH TO BREATHE. FIELD CROPS CANNOT DO THIS SO THE EXCESS OF MOISTURE MUST BE DRAINED AWAY legumes is also drawn from the soil air. This air circulates through voids or pores which are stopped up by excesses of free water that cannot drain away. Such a condition stops the actions just described, and must be guarded against by keeping free water drained away from the active feeding zone of the roots. When the water table is within the reach of the deeper roots, small feeders are sent down to or near the water surface and drawn from the moister soil there.

Cultivation and Yields.—The easiest soil to plow or cultivate is one that has all excesses of free water drained away, and has dried a little so that it will crumble rather than break in lumps. A wet, soggy soil is not only hard to cultivate, but the very act of working it injures instead of being a benefit. The air is worked out, and the air spaces themselves are closed by the process, and the granulation is destroyed. A very dry soil breaks up cloddy, and the condition produced by plowing it when it is in this condition is sometimes nearly as bad as if it had been plowed wet. The proper storage of capillary moisture by good cultivation is the only safeguard to maintaining the proper tilth of the soil and to prevent puddling or the formation of clods.

The aim of the farmer is to produce crops at a profit. Water is the cheapest article he has to handle, and is at the same time one that allows itself to be handled almost at will, but becomes a serious drawback if allowed to take its own way. It must be there as a food and a carrier of other foods, as a control of the temperature of the soil, and to insure the proper granulation of the soil. Everything that can be done to the soil in the way of getting rid of excesses of free water and holding the maximum of capillary water will make itself known in the increased yields it affords.

Erosion.—Erosion or washing steals plant food. If bad, it takes the whole of the surface soil away. An excess of water often causes damage by erosion. In addition to taking away valuable plant food and the cultivated top soil, erosion leaves the fields cut up and rough and exposes material that requires

U. S. D. A.

A BADLY ERODED HILL

much effort and long exposure to weathering before the plant food reaches a satisfactory state of availability. Gentle, slow rains are always preferable, because they have more time to soak into the soil, but as the intensity of rainfall is beyond the control of the farmer, he must fortify his soil against attacks of erosion due to heavy precipitation or large amounts of rainfall in a short time. The answer is to get the water down into the soil before it can run off. It is a difficult matter to do this in a big wash, where thousands of barrels of water are coming down, but these large washes are started by little trickles of only a few spoonfuls further up the hill. These little trickles start because the soil is too tight for the water to enter. The surface may be sealed over by a little crust or there may be plow sole, tight clay, or hardpan deeper down which limits the soils absorption to the immediate surface. The correction of such conditions prevents the wasting of the valuable soil into the drainage courses. The surface crust can be destroyed with even the lightest tools, and a deep shattering by blasting will open up the subsoil so that it will be able to absorb hundred of gallons of water, where before it took but sparingly.

Clemson College S. C. Bulletin

EXPENSIVE TERRACING TO PREVENT EROSION

Drainage.—Attention has already been called to the necessity of removing all excesses of free water. Where such excesses are caused, as they so frequently are, by the water being held on or near the surface by hardpan or other impervious material below, the trouble may be overcome by breaking through the holding material into more open material below. The full extent of the possibilities of this method of drainage have not yet been developed, and it is quite likely that many of the upland swamps will later be entirely controlled by this method.

A more rapid development of the larger swamp areas has been retarded on account of the great expense of ditch digging by hand or by the machines suitable for digging under such conditions. Again, a rational use of dynamite has answered the question, for it has been absolutely proven by experimentation and practical application on large and small drainage areas that ditches can be quickly, economically and satisfactorily excavated by blasting. The wet soils of the swamps and overflowed regions have made digging by hand expensive on account of the difficulties encountered by the labor, but swamp water has no terror for the swift cutting action of a high power dynamite that will rip open a long stretch of large or small ditch at one effort. Such a blast not only opens the ditch, but levels down the harmful spoil pile or bank, scattering the dirt over the adjoining land for a distance of over a hundred feet.

A BEAUTIFUL BLASTED DITCH

Ditch blasting is by no means limited to wet lands, for it is being successfully used in excavating even in dry hill soil, provided it is not sandy. Changes in the soil or the soil condition require changes in the selection of the explosive and the method of loading, which are details that can best be learned from the books of practical instruction of the manufacturer or from one of their representatives.

The use of blasting in connection with drainage is not limited to the shattering of deep drainage courses to permit of downward drainage, but is being used largely in connection with open and blind ditches where the subsoil is so hard that it prevents the passage of the water into the drainage channels.

Thorough subsoil blasting opens up these subsoils and permits the drains to collect and carry away the water that has rendered the fields worthless.

Dynamite and farm powders are also being used to control old-established gullies or washes. The banks are shot down into the bottom of the gully so that teams can be driven across to plow the banks down to the desired level. This shattering also loosens deeply and increases the immediate absorption of water and benefits further by holding out of the surface drainage much of the water that before increased the run off and attending erosion.

QUESTIONS

1. What is the amount of the annual rainfall in your part of the state?

2. How is this distributed during the year?

3. Which of your crops suffer most from lack of water? Why?

4. Describe your ideal method of storing water on your farm for the use of crops?

5. What have been your experiences with deep plowing?

6. What is your method of controlling erosion, and what results have you obtained?

7. What modifications in your practice of controlling erosion do you think necessary?

8. Describe an ideal plan for the general drainage of your farm, that will include the control of the hill water as well as that of the bottoms.

9. What is the best method of correcting a small stream that has a crooked, shallow bed?

VERTICAL FARMING

PART IV

Soil Bacteria

The most constantly active part of the soil is its bacterial life. These are tiny little plants that are very close to the border line of being animals, and are known by a number of popular and slang names. They are the smallest known living organisms. Some are so small that 50,000 of them lying side by side would not measure over an inch, and a single drop of blood or milk would form a desirable tenement for thousands to live in and multiply. They reproduce very rapidly, usually in from 15 to 45 minutes. If unchecked, a single bacterium could multiply to 17,000,000 in 24 hours. This reproduction is seriously checked by lack of room, insufficient food and unfavorable surroundings, such as lack of air or too much water for some and the reverse for others. They are also checked in their development by the presence of their own excreta. They form spores for their reproduction and for preservation and distribution. In the spore stage they can live over long periods of conditions unfavorable for their growth and reproduction, and then begin their work again when conditions are favorable. The total number of bacteria is inconceivable, for they are in the air, water, soil, and everywhere.

Some of them are harmful, and their development should be checked, while others are so helpful to mankind that every effort should be made to encourage their growth. The different forms require widely different conditions for their best growth. One class thrives in an abundant supply of air, and are called "aerobic." Another form, "anaerobic," get their oxygen from breaking down compounds containing this element and thrive best in places that are not well ventilated. The first named form includes the beneficial forms of soil organisms, while those of the second class are usually harmful. The very cultivation and aeration of the soil, therefore, promotes the growth of the beneficial forms and checks the activities of the harmful ones. The deeper the soil is loose and well aerated, the deeper the helpful forms are found.

DIFFERENT FORMS OF BACTERIA (GREATLY ENLARGED)

Harmful Bacteria.—Some forms of bacteria produce destructive diseases in the plants, both in the tops and branches and in the roots. The greatest trouble from bacteria in the soil, however, comes from the forms that attack the nitrogen carrying foods and cause the nitrogen to be unlocked from its combined form and to escape as gas. These forms thrive best in wet and packed soil, where they cause the organic substances to undergo a wasteful putrefaction rather than a beneficial decay. Their activities are at once checked by the presence of free air. Some crops grown continuously on the same soil for a long time cause it to become filled with forms that cause diseases in the roots. Generally these can be destroyed by a rotation of crops attended with deep tillage.

In short the control of harmful soil organism is accomplished by thorough drainage and good, deep cultivation. Many of them seem to thrive best in sour soils which can be made sweet and desirable for the beneficial forms by additions of lime.

Beneficial Organisms.—Bacterial action is beneficial to agriculture in many ways. As soon as a plant or animal dies, the influences that have restrained the action of the organisms of decay are removed and the bacteria at once begin breaking down the complex organic substances into forms that are again suitable for plant food. In this way they are the health patrol, the scavengers of the soil. Some forms have the power of liberating food from the insoluble mineral soil grains and are the fairy chemists whose laboratory is the surface of the soil particles. These soil builders have already been described elsewhere is these articles.

In fact there are millions of these tiny forms that are eager and willing to assist the farmer and gardener if given proper soil atmosphere, proper soil moisture, and proper soil temperature.

Nitrogen Fixing Bacteria.—Attention has been called to the likelihood of a deficiency of nitrogen in the soil and the high cost of replenishing the supply through the use of expensive fertilizing materials. Certain of the air-loving bacteria form little colonies, called nodules, on the roots of leguminous plants and take the free gaseous nitrogen of the soil air and tie it up in compounds that furnish the nitrogen fertilizer to the higher forms of plants. These bacteria do not thrive in either a wet or a sour soil, and are not found naturally in the soils of many parts of the country. They can be planted or started in such soils by the use of certain commercial cultures, or by additions of soil in which they are known to be present. Abundant supplies of these bacteria are necessary in the soil before it is possible to get a good growth of the most beneficial legumes without robbing the soil of the supply of nitrogen al-

NODULES ON ROOTS OF A LEGUME

ready present in a properly combined form. Even in soils rich in nitrogen the growth of these crops is materially benefited by the presence of the bacteria.

Other forms of bacteria and kindred plants of microscopic size have the power of gathering bacteria from the soil air and their development should also be encouraged. These forms are not so well known as those that produce the nodules on the roots, but their benefits are marked. They demand a well drained and well aerated soil.

Helping a Friend Along.—Aside from the nodule forming bacteria, most of the other beneficial forms are found in all normal soils. It is not necessary to add them in artificial cultures, but their activities can be materially increased by keeping them in suitable surroundings and supplying their constant but simple desires. These forms get their oxygen from the air, and must therefore not be closed up in a tightly sealed soil. They do not thrive in the deep subsoil unless it is well aerated. Large excesses of water that clog up the pores of the soil also

SWAMP CONDITIONS OR EXCESSIVE AMOUNTS OF WATER SEAL THE SURFACE AND STOP BENEFICIAL BACTERIAL ACTION exclude the air and smother out the good forms, but permit the harmful bacteria to grow at will. While too much water is bad for them, too little water also retards their work. A good moist soil, just about what the plants want, is their favorite —in short, a well drained soil. Most of them need a supply of organic matter, such as partly decayed plants or animals. This is also just what the plants want. Another one of their desires is for even tempered soil, where the changes are not too sudden from hot to cold. Here again they agree absolutely with the plants. In fact the beneficial bacteria and plants seem to be such good friends and neighbors that anything that benefits one equally benefits the other, and if one feels sick, the other wants the doctor also.

In keeping up the bacterial activities care in turning under green manures or additions of litter or manure is always repaid many fold. These additions of humus forming material also assist greatly in maintaining the needed moisture supply as humus has a wonderful power of absorbing and holding water and also assists in granulating the soil.

More About Nitrogen.—Free nitrogen is everywhere. The air over a single acre contains about 75,000,000 pounds of this peculiar element. To buy a pound will cost from 15 to 20 cents.

TWO SOURCES OF NITROGEN
HOME TRAPPED BY LEGUMES—BOUGHT AT GREAT COST

The farmer, through his good little friends, the " bugs," traps and stores this in his soil, provided he goes about it in a business-like way.

This way is simple. Prepare the soil for the best content of moisture and air, and see that it is not sour. Be sure that the right bacteria are present, and then grow deep rooted legumes that suit the locality best. Selections of legumes can be made for practically any purpose. Some of them yield the most nutritious hay, while others furnish grain that is good for food for both man and all kinds of farm animals. Others furnish excellent pasture. Some are best suited for soil building in the shape of green manure.

The deeper the preparation of the soil the better the results that are obtained. A few inches of loose soil will give just so much room for these activities. A few inches more will be of benefit, but the desired production cannot be reached until the air-loving bacteria and the deep-rooted plants have several feet of good mellow soil in which to operate. The only satisfactory method of effecting such deep tillage is by blasting.

A ROTTING LOG. BACTERIA MAKE HUMUS OUT OF EVEN THE LARGEST AND HARDEST PARTS OF PLANTS

QUESTIONS

1. Are the changes due to the rotting of a plant or animal under water the same as rotting in the air?

2. What are the most noticeable differences you have detected in the two kinds of rotting?

3. What are five beneficial effects of bacteria on the farm?

4. What are five harmful effects of bacteria on the farm?

5. How would you prepare a bottom having a cold, wet subsoil, and drained by a deep open ditch, for growing ordinary field crops?

6. How would you prepare a tight hillside subsoil, low in lime, for growing alfalfa?

VERTICAL FARMING

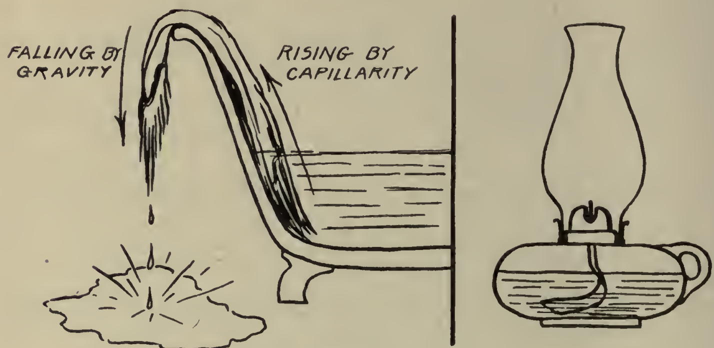
PART V

The Movement of Moisture and the Feeding Zone of Roots

The movement of moisture in the soil is of the utmost importance to plants. It is first necessary that the water received from rain or irrigation should move downward through the soil, leaving behind only such as is held by capillary attraction. The excess should move out of the soil and into the drainage. This movement of moisture is entirely one of gravity. Water moving in this way is called " free water."

Movement of Water by Gravity.—In order to get the water down into the subsoil and prevent its running away as surface drainage, or standing on the surface and stopping all possibilities of air circulation through the soil pores, it is essential that it move downward very soon after it is deposited on the surface. This movement depends on the openness of the soil. Sometimes in a sandy soil the water soaks into the soil too rapidly and too much drains away, but such is not the case with clay and other dense soils. In such soils the pores are naturally small and the water is held back. The movement can be hastened by tilling or stirring the soil to the depth to which it is desirable to carry the water. The deeper this can be made effective the better, and so it is very apparent that soils where the water is likely to stand on the surface are in need of the deepest practical tillage. As the free water clogs the pores and stops many of the soil processes, the plants do not draw their moisture from it, but get it instead from the smaller capillary supply left behind.

Movement of Capillary Water.—The capillary or film movement of moisture takes place in all directions, but its most important direction is upward. When tight soils prevent the downward percolation of free water, some is carried downward by this pull which has been described elsewhere as the same movement as the oil moving in a wick. As the amount of moisture that is held by capillarity is limited and if not replenished, the supply within reach of the roots may soon be exhausted. This available supply is partially maintained by the upward movement of capillary water. As one point becomes dry, the water is drawn from below by a constant pull on the thin film. When capillary water moves from the more abundant supply below, it brings with it soluble plant foods to assist in nourishing the plant.

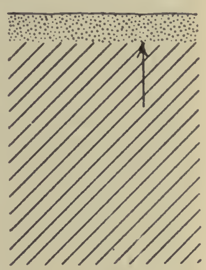


TWO EXAMPLES OF CAPILLARITY

The movement of capillary water is effected by several conditions. It is governed very largely by the texture of the soil. The finer the soil and the more surface the soil particles expose, and the more points of contact between the particles, the greater is the pull. For example, a heavy clay soil containing 20 per cent. of moisture may draw water from a coarse sand containing only 10 per cent. Sandy or coarse soils move water very rapidly and in large amounts, but the movement in such soils cannot take place over long distances. With clay, which has a much stronger capillary pull, the movement is much slower, but may take place over greater distances against gravity. The amount of moisture moved in this way decreases as the limit of distance is reached.

In addition to the texture, the structure of a soil has an important part in governing the capillary movement. The better granulated a heavy soil, the greater the pore space and consequently the greater the pull. Additions of humus materially increase the capillary pull as well as the reservoir capacity of a soil. In a puddled soil the movement is very slow and the amount of water moved very small. The denser the soil becomes, the slower the movement.

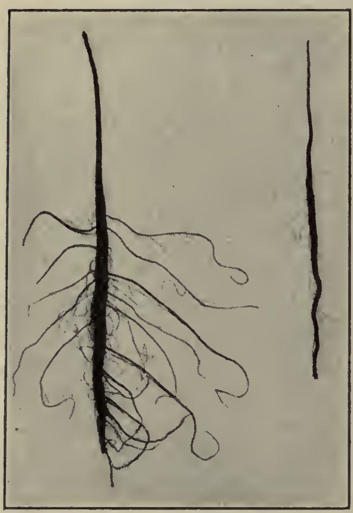
Dry layers of soil break off the capillary pull on account of the coating of the soil particles being of such a nature that they resist wetting. It is this fact that makes the effectiveness of a dry dust mulch, in holding the water below the surface and not allowing it to rise to the surface and be lost by evaporation. Capillary movement is much faster in wet or moist soils than in dry ones, so it is advisable at all times to preserve some moisture in the soil if only for its benefits in a rapid equalization of the moisture content when water is applied. The ratio of the movement in wet and dry soils has been shown to be as high as 1 to 4.



THE CAPILLARY RISE OF MOISTURE CHECKED BY A DUST MULCH

This upward movement continues to the surface and when allowed to go unchecked will result in all the movable moisture being pulled up and lost by evaporation. The rate of evaporation of moisture from the surface is governed largely by temperature and wind velocity. When water is stored at great depths in the soil it is harder for it to be pulled to the surface and lost. This surface loss at times approximates an amount equal to a sheet of water 5 inches deep, over the whole surface in a month. A handy example of the upward movement of water and a check to its loss can be observed by turning over an old log or plank that is lying on the ground and noticing the large amount of water in the soil immediately underneath.

The Feeding Zone of Roots.—The root systems of plants require as ample room in which to develop as does the stalk and leaf system above. Roots must both anchor the plant in place and reach down for food and water. The feeding zone of a plant determines the amount and value of the top. The soil must be cultivated in order to provide a proper feeding zone, for the earth in its natural condition will not yield as abundantly as well cultivated soil. Just below a good surface mulch in a well cultivated field we find moist soil full of roots revelling in an ideal feeding zone. On an adjoining uncultivated field one must dig down to find moist soil, and discovers only a few roots feeding in a meager compact feeding zone. Rootlets are ever pushing into fresh soil zones where more water and food are to be found, yet the feeding zone in ordinary farming is confined largely to the shallow depths of the plowed furrow, simply because it is the only warm, mellow, well ventilated soil within the reach of the roots. When given a chance, feeding roots advance rapidly to meet the capillary rise of soil moisture, and the energetic way in which they go down and search in every direction for food and water proves them to be highly organized parts of the plant and possessed of instinct or something akin to intelligence. Plants having large or active root systems, making a rapid growth, remove more water and more plant food from the soil in a given time than those with a small system or



PECAN ROOTS FROM BLASTED AND TIGHT SOIL

ROOTS GOING DOWN FOR FOOD AND WATER. THE DEEPER THE BETTER.

sluggish action. A corn crop when in the season of most vigorous growth will remove more water from the soil in a day than will a crop of wheat. Some crops are slow, weak feeders, while others feed ravenously, and, while taking up more substance, may be able to overcome more unfavorable conditions. Roots should be thrown down into the soil as far as possible in order to get away from danger of drouth, and excesses of temperature, as well as from injury by cultivating machinery.

The desirable conditions for a root system can be improved by thorough cultivation of the subsoil, much deeper than any plow can go, by means of explosives. They loosen up the soils so that the roots are not checked in going downward, the rise of capillary water is aided, aeration is improved, and deep reservoirs of water made accessible. This method more than doubles the depth of the feeding zone.

Depths to Which Roots Go.—The natural tendency of most roots is to go deep into the soil. Many who have not investigated this subject believe that roots do not go deeper than one or two feet and cutivate accordingly. On the contrary, they go to much greater depths if the soil conditions permit. Corn roots that have been confined and have occupied all the soil to a depth of 2 feet, will go to a depth of 8 feet if the restriction is removed. Wheat, oats and barley will penetrate from 8 to 10 feet, grass roots will go down 6 and 8 feet, while alfalfa has been known to go down over 30 feet. Grapevine roots have been found 22 feet below the surface, while the root systems of trees correspond in extent and branching to the parts above ground. The roots of clover weigh as much as the total weight of the year's crops, while the roots of an oat crop are nearly 50 per cent. of the weight of the seed and straw. The total length of all the roots of a wheat plant was found to be about 268 feet, of one rye plant 385 feet, and of one corn plant 1452 feet. Such facts show that the size and depth of the root systems are generally not appreciated, and are generally underestimated. It is evident that the roots need a far deeper feeding

Courtesy Prof. Ten Eyck, Kas. Expt. Sta.

DEEP ROOTING OF CORN AND ALFALFA

zone than is ordinarily given them. The feeding zone has been shallow and meager, largely because the farmer could formerly find no suitable means for the deep cultivation. No practical machinery can till the soil as deep as 2 feet, and even that limit is not sufficient for the needs of crops. Such deep cultivation is possible only with high explosives.

The benefits of deep rooting of a crop do not pass away when the crop is harvested, for the roots are left down where they grew, and on decaying form humus at a depth where it would be impossible to place it by artificial means, down where it will help to perpetuate the granulated condition of the subsoil, and keep alive the deep feeding and working bacteria, helping the farmer to gain thereby the full return from all of his field rather than from the top only.

Weeds and Their Effects.—Weeds injure crops by robbing them of their water and food. The escape of water is intangible, like the setting free of plant food, because we cannot see either with the eye and must put our wits to work to detect its departure. Weeds may have a mission in life; anyway they are

WEEDS—THE STAR BOARDERS

stimulating rascals. When the farmer gets mad enough to go after them, their mission is ended, for by destroying them he conserves the moisture by unconsciously cultivating the ground and increases the fertility of the soil.

Conserving the Moisture.—Where the moisture supply is deficient, weeds should not be allowed at any time before, during, or after the crops, for they remove water from the soil as rapidly as the useful plants. When the water is ample, but the soil too fine to permit rapid enough capillary movement, green manure should be grown and plowed under deeply. The chief feature in conserving moisture is, of course, to get the moisture in hand. This can only be done by leading it down into the soil to great depths. If the soil is of such a nature that this takes place of its own accord, all well and good, but many soils are not that way. They are stubborn, and need a real first-class shooting with an explosive to subdue them. Then the maintenance of the organic matter and surface mulch can reach their desired effects.

QUESTIONS

1. What soil conditions cause water to be held on the surface of fields?

2. Will oil rise faster in a moist or dry lamp wick? Will the same principle always hold true of soils?

3. Why does a dry layer of soil stop the capillary rise of moisture?

4. When should a dust mulch be renewed?

5. What effect would a few inches of loose straw on the surface have on the soil moisture during a rain? During hot, dry weather?

6. Why is it beneficial to fall plow and deep till thin, hard lands and cover the surface with trash?

7. Which will you find at greater depths, wheat or clover roots?

THE PLOW GIVES THE IDEAL SURFACE BREAKING BUT ONLY EXPLOSIVES CAN ATTACK THE DEEP TROUBLES

VERTICAL FARMING

PART VI

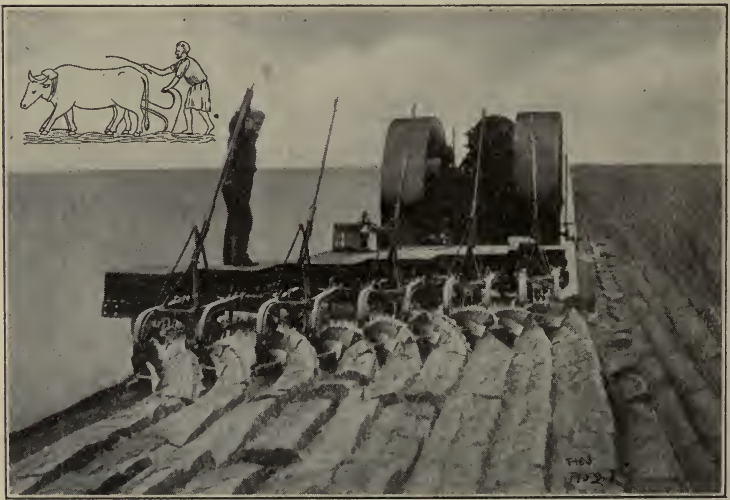
Cultivation—Use of Explosives

The present means and methods of cultivation are behind the times. They are not up to date with the progress made all along other lines. They all work too shallow, cultivating the land a few inches where they should loosen and stir to a depth of several feet. A world of wealth in thought, money, invention and machinery has been bestowed upon the first few inches of the soil at the surface, but up-to-date agriculture demands that the depths of the soil be considered also. It is not enough to just scratch the surface and leave untouched the storehouse of wealth below.

A World of Tools.—The farmer has at his command for working this thin skin of the surface inches a wonderful array of tools. He has plows of all kinds and qualities to select from to fit every surface condition imaginable—hillside, landside, hinge, and swivel plows—equipped with every shape of moldboard, and coulters that may be fin, knife or rocking. He may use hand, sulky, or motor plows, and work them single, double, or in gangs. He has harrows without number, home-made and latest patent, coulter, spring, chain, slicing, spading and cutaway, all of them equipped with teeth set vertical or set slanting, with plain, twisted, shovel, coulter, spike, and spring teeth in a bewildering dental display. He has cultivators of all sorts and breeds—hand, walking, and riding. He has drags, rollers, plankers, floats, boats, clod crushers, pulverizers, and smoothers, and he has so-called subsoilers in good variety that work only a few inches deeper than the tools already mentioned.

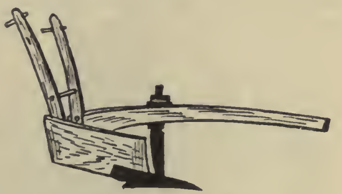
Yet with all this to select from he can do but little better than the Romans did—prepare the seed beds and scratch the surface, while at greater depth the roots still have to scratch for themselves, as they did centuries ago. It is too much on the principle of the man who only greased the front wheels of his wagon, saying that if they went the hind ones would "just naturally have to follow."

Progress Demanded.—With lands becoming scarce and prices higher, there is a demand for methods that are more efficient, that will cultivate the ground to greater depths, that will meet the demands of the feeding roots, that will double the feeding zone, that will furnish deep moisture reservoirs, that will extend bacterial activity downward, that will double and treble the farmer's acreage of productive soil by depth, and not by area. So far as these demands are concerned, farm machinery is so far a failure and but little advance has been made on the primitive plow, the sharp stick with a V-branch. It is not



MARVELOUS IMPROVEMENTS HAVE BEEN MADE IN SURFACE CULTIVATION enough to secure ease of draft, or raise heavier and faster walking horses. It is not enough that the ox, horse and mule are giving way to steam, gasoline, and electricity, to cable traction and automobile luxury. It is not enough to point with pride from the one-negro-one-mule-one-plow combination to the monster steam gang plows. Something more is demanded. The present machinery is good *sa far as it goes,* and is the best that the world has ever seen until recently, but *it does not go far enough.* It does not go down. Many remedies have been suggested only to meet with a cold reception. It is always difficult to change old conditions, old customs, for there is ever prejudice against such changes. The kind of prejudice that the first cast iron plows (Newbolds, 1797) " poisoned the land " and " caused weeds to grow " is still in existence, and can only be overcome by enlightenment.

PLOW USED BY THE ANCIENTS



EARLY AMERICAN TYPE

Shallow Methods Prevail.—All methods and machinery in common use are good for preparing the seed bed, but are of little or no use in helping the roots to go down to their natural length; of no use in improving the soil atmosphere more than a foot or two, or in meeting the many and varied demands of the plant system below the surface. The function of the plow is essentially to turn a thin ribbon of the soil on edge or upside down, and to shatter and break the surface of the earth as much as possible, and to destroy weeds, and bury refuse. Harrows and cultivators have primarily a stirring action that forms mulches and prevents surface evaporation, but they work at even shallower depths than the plow. Some of the instruments used tend to form plow sole, or hardpan and impacted conditions of the soil close to the surface, defeating the very object of cultivation.

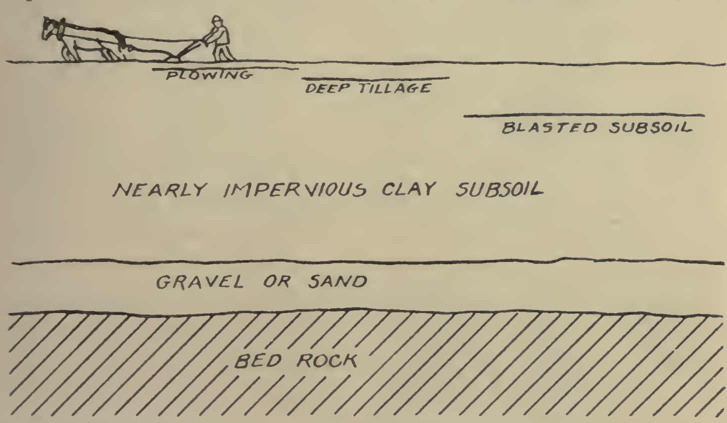
The most effective of all farm tools in breaking up the surface soil is the plow, and its use in working up a tight surface soil into a satisfactory condition of tilth must never be overlooked. The effectiveness of the plow has been improved by using modifications that will disturb the soil to greater depths than is possible with an ordinary moldboard plow. The best known tool of this type is the narrow subsoil plow that follows along in the freshly turned furrow of the regular plow, deepening the cultivation several inches. Such a plow does not bring the subsoil to the surface but simply stirs the subsoil. The depth reached is seldom as much as 18 inches and is usually not more than 12 to 14 inches. A more improved implement is the new double disc Spaulding Deep Tilling Machine, which combines in one tool both the surface

COMMON SUBSOILER

SPAULDING DEEP TILLING MACHINE

and the sub-surface plow. One heavy disc follows behind and below another, and by their cutting, twisting action break and mix the surface soil with a layer of the material lying underneath. Excellent results have been obtained with both forms of deep plows, and their use is strongly recommended, as their immediate action is to break up the plow sole or shallowest hardpan material. They also leave the surface and immediate sub-surface in a most desirable condition to receive the rain water and allow it to be conducted to the deeper subsoil that has been shattered with an explosive, where it may be held by capillary absorption.

Benefit of Using Explosives.—It is admitted that present methods of cultivation do not go deep enough, and it must also be admitted that the use of specially prepared agricultural explosives offers the desired remedy. It is admitted by all

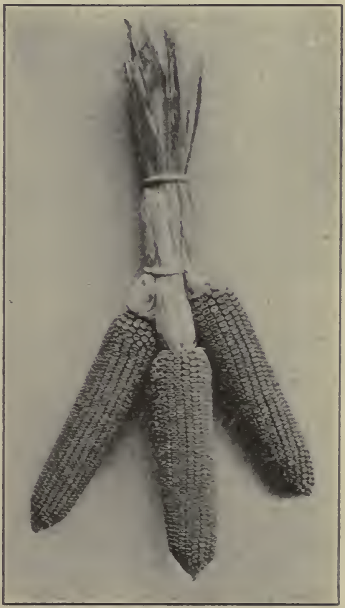


COMPARATIVE DEPTHS REACHED BY DIFFERENT FORMS OF TILLAGE

authorities in agriculture that the plow and harrows do not go deep enough and they advise the use of subsoilers. Scores of books explain how and why each piece of machinery turns over the soil, reduces it to fineness, forms mulches, saves water, breaks clods, aerates, stimulates bacteria, etc. If all this wealth of invention and labor *is worth while bestowing upon the first few inches* of the soil why it is not worth *following the roots* *down* to their second foot of growth, their third, and even their eighth and tenth foot when they flourish at those depths. The only reply is, " Yes it would pay, but how can it be done? ". It can be done economically, quickly, and thoroughly by the use of explosives. Deep plowing is recommended by all authorities " wherever the resisting soil will permit." Machinery made especially for deep work may be stopped, but nothing can resist the explosives. The farmer plows, harrows, and spends time, labor and money in cultivating the surface foot and rejoices in the wonderful alchemy that follows his endeavors—the mysterious activities he has set in motion. He works cheerfully and with confidence, largely because he can see what he is doing. In the new agriculture he must work by faith and reason in depths where he cannot see with his eyes what is taking place. The result will place before his eyes in the form of bumper crops proofs of the benefits of his work. The new agriculture simply points out the benefits acquired by the thorough cultivation of the foot, or two feet, and by explaining how and why this is accomplished, points out the value of extending the cultivation further down by the simple means of explosives. The harrow warms and aerates the soil and promotes activity by loosening and separating the soil particles at the surface. Explosives do the same, breaking, loosening, pulverizing at depths machinery cannot reach. Drainage is recommended by all because it removes excess of water, admits air, and gives proper moisture conditions. Explosives have drained many a field and secured all these benefits at far less cost in time, labor and money than the usual methods of ditching and tilling.

The importance of nitrification is proven, but why confine it to the thin furrow slice when the action of bacteria has been proven at depths of 6 feet in the humid soils of the East, and still deeper in the porous soils of the arid and semi-arid regions of the West? Why not loosen the soil and secure proper conditions by the use of some charges of explosives? It is admitted that there is much of plant food below the shallow plowed and cultivated ground, and that the roots will go down if they can. Why not open the way and make it easy for them by cracking and pulverizing the soil with explosives as far down as the roots care to go? It is admitted that water may be stored, as in dry farming, by converting the soil itself into a reservoir by making it porous so that it absorbs water and holds it like a sponge. Why not use explosives and make the reservoirs two and three times as great and secure absolute instead of partial insurance against drouth?

It is admitted that much of the rainfall is lost by running off, and consequent damage done by erosion. Why not check this by the use of explosives before the rainy season, storing the rainfall in porous soil instead of letting it run to waste? It is admitted that some of the soils called "wornout," or "poisoned" and "worthless" may be reclaimed if the soil is thoroughly stirred up from the depths. What can do this so efficiently as explosives? It is admitted that much of the plant food in the soil is unavailable because it is unweathered. Why not make it available by opening the ground to weathering agencies by explosives?



FROM DEEP SHATTERED SUBSOIL

The benefits of clean summer following every other crop, under low rainfall, and occasionally under abundant rainfall are admitted. Why not secure these benefits by means of explosives? It is admitted that granulation of a soil is a benefit, that any treatment that increases the lines of weakness in the soil structure facilitates the movement of capillary water, and the action of moisture films. The more numerous the lines of weakness the quicker granulation is secured.

The fewer the lines of weakness the more close and cloddy the structure. What will granulate soil to the depths quicker than explosives? It is admitted that present machinery can only increase the feeding zone of the roots an inch or two. What can explosives do in this line? A cubic yard of hard soil has 6 faces and 9 square feet in each face, or a total of 54 square feet. Divide it into 1 foot cubes and there are 162 feet of surface. Break it into inch cubes and it presents 1944 square feet, or nearly 1/20 of an acre of feeding surface for the roots.

TOY BLOCKS TO REPRESENT THE INCREASE IN SURFACE AREA—THE REPRESENTED CUBIC YARD HAS A SURFACE AREA OF 54 SQUARE FEET. THE 27 CUBIC FEET A SURFACE OF 162 SQUARE FEET. IF BROKEN TO INCH CUBES THE AREA IS 1944 SQUARE FEET

SHATTERING SUBSOILS WITH FARM POWDER

A single cartridge of explosive can easily convert several yards of compact and useless hardpan into *half an acre* of new feeding ground. Costly, massive, improved machinery enables the farmer to spread out his operation, to move horizontally, and handle more acreage in the same time, and he is ever eager to double and treble his holdings of fertile soil. What is wanted is something that enables him to move vertically down and double his acreage, and double his yield by doubling the fertility of the soil, by doubling the depth of the feeding zone, by doubling the water supply, by cultivating the ground to double and treble the former depths. "*Vertical Farming*," to coin a name, is the keynote of a new agriculture that has come to stay, for inexpensive explosives enable the farmer to farm deeper, to go down to increase his acreage, and to secure larger crops. Instead of spreading out over more land he concentrates on less land and becomes an intensive rather than an extensive agriculturist, and soon learns that it is more profitable to double the depth of his fertile land than to double the area of his holdings, and he learns that his best aid and servant in this work is a good explosive. Peace congresses demand that swords be turned into pruning hooks. The farmer is busy turning explosives from war to agriculture, from death dealing to life giving work.

There is a demand to-day for farmers who think, and who think long and closely as well as observe; for men who reject nothing because it is an innovation, because it is new. Men are wanted everywhere who have thought for themselves how soil first came into being and what its form and character are and what they mean; men who are not satisfied until they know how plants feed, where they feed, and the nature of their food; men who look below the surface of the ground and realize that as much of their future crop is there as will be above the surface, that plant roots must have air and water at the right times and in the right abundance as much as the animals in their barns.

This kind of men have been and are using explosives freely as the best and simplest means of securing success and accomplishing their object. Their success may be duplicated by all who care to do so. The use of explosives for deep cultivating and other farm purposes has come to stay.

Vertical farming with explosives is another step forward as truly as irrigation and dry farming, and is greater, for unlike them it is not limited to any area or region but may be practised everywhere and anywhere. It has the world for its field.

QUESTIONS

1. What is your investment in tools per acre of land tilled?

2. What is your total cost of preparing, seeding, cultivating, and harvesting one acre of money crop?

3. What improvements over the practices of your father have you made in the use of field machinery and supplies?

4. How deep do you actually plow? (Measure the depth at the unbroken side of the furrow.)

5. Did you ever follow up the full development of the roots of a tree or a field plant? What did you find?

6. Have you any actual knowledge of the character of your subsoil?