Some Soil Management Practices That Pay

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A subject as broad as this one allows considerable latitude in discussion. I used the words "some practices" so that I would be under no obligation to discuss everything. I can discuss what I want to. This being so, I will limit the discussion to the western irrigated region, and will emphasize practices that are important in growing sugar beets.

It is not necessary to tell those of you who have herded a stream of water over a farm that irrigation farming is different. Yet it is necessary to discuss some.of these differences so that we may have a full appreciation of the problems of soil management under irrigation and be able to capitalize on the experience gained in other regions as well as in our own. Supplementing rainfall with irrigation water adds certain complexities to farming, yet many basic principles of soil management, have universal application.

In undertaking the utilization of the arid lands of the western United States through irrigation, conditions and problems have been encountered that are new to our race. Our agricultural people have been since the beginning of civilization accustomed to farming under rainfall. The engineers who have planned and built our irrigation works have had to meet and solve many new problems, not only in connection with the construction work but more particularly in the continued profitable use of water in agriculture. Irrigation farming may be older than any other kind of highly developed agriculture, but the people of northern Europe who have contributed so largely to our population and occupied our agricultural lands have had no practical experience with irrigation. The engineers who constructed and operated the extensive irrigation works of antiquity in western Asia and northern Africa have left few written accounts of their work, and the problems and difficulties of the men who farmed those irrigated lands have not been recorded. There are evidences that Irrigation was used both in North America and in South America long before the arrival of Columbus. In Peru and along the Gila and the Santa Cruz in Arizona the discoverers found irrigation in use to a limited extent, and it is now known that there were much more extensive irrigated areas that had long since been abandoned, as for example the Salt River Valley of Arizona.

There have been a number of instances both in this country and in the Old World where the productivity of irrigated land has been

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comparatively short-lived. In some of these the causes have been obvious; in others, obscure. There appears to be no valid basis for the view sometimes advanced that irrigation farming cannot be continued indefinitely on the same land. Nor is there much foundation for the belief that irrigated lands are made increasingly productive by the salts carried in the irrigation waters.

It is an outstanding characteristic of our arid lands susceptible of irrigation that within a restricted area they are more variable in character and in potential productivity than the lands of humid regions. This fact is due to the nature of their origin and formation. For the most part these irrigable lands have been made along river channels or delta cones. The soil deposited by flood waters may vary from gravel to clay within a few feet, either laterally or vertically. Even where the surface topography is uniform the surface soil may vary in texture and depth between wide limits. The farmer who says, "My soil is different," is usually right.

Added to this initial variability in soils is the complication that these soils developed under scanty rainfall and sparse vegetation. When a farmer starts out with a soil that has developed under perhaps 10 inches of rainfall and then adds possibly 24 to 48 inches of irrigation water a year, which results in much greater production of vegetation, he violently interrupts all of nature's processes and starts a whole new sequence in soil development. His soil was not only different to begin with, but the farms a different soil each year.

If irrigation water were as pure as rain, marked changes would occur in soils as a result of this change in soil climate. But irrigation water is not as pure as rain.

Mark Twain has recorded the observation that you cannot tell by the looks of a frog how far he can jump ; an equally vivid observation is that you cannot tell by the looks of irrigation water how much salt it contains. It is a fact that all our underground and stream waters used for irrigation contains salts in solution. The quantity may be small, but they are always present. Furthermore, there are many different salts jn these waters, some of which are beneficial to crops, some harmless, and others injurious. The variable quality of irrigation water used in different areas combined with the variability in soils introduces many complexities into the problem of achieving sustained production through soil management.

As a business enterprise irrigation rests on the tacit assumption that it will continue to be effective and will produce undiminished crops for generations to come. Unless that assumption is valid, the whole of the vast financial and social structure of irrigated agriculture must crumble. Considering all the evidence, we must admit that in many districts crop yields are decreasing—and this not because of less careful or less expert farming but because of obscure factors that lie beyond the farmer's work. Weather, plant pests, and similar crop hazards are not to blame, but on the contrary the formerly satisfactory system of farming itself seems to be at fault. Fortunately, we now know some of the reasons for these declines in yields and have demonstrated in the field ways to prevent them.

Our irrigated lands occur as compact, sharply defined areas, isolated from each other and widely scattered over the western United States. Each has its peculiar combination of climate, soil, and water supply. Each has its own problems and possibilities of crop production and markets for its products. It is very exceptional that the lessons of experience acquired in one of these irrigated regions can be applied with the same success in another. Yet, as I see it, there are five well-paying practices that have general application.

It pays to adjust irrigation methods to soil, water, and crop

In the early days of irrigation in this country it was not uncommon for farmers to use excessive quantities of water. Where the land was rough and water was abundant it was easier to use large heads to cover the land than to level the land and economize with the water. Such wasteful methods of irrigation have largely been abandoned. The evils resulting from them were too obvious to escape attention and are too well known to need elaboration here. The reaction from the earlier excessive use of water has been stimulated by much well-intended propaganda. The irrigator has been urged to use water sparingly, not only in order to permit the fullest utilization of our limited supplies but also for reasons of more direct self-interest. It has been alleged that the liberal use of water not only leaches the fertility from the soil, but also that it contributes directly to water-logging the subsoil and thus necessitates artificial drainage which would not be necessary if water were used more sparingly. The ideal system of irrigation as portrayed by some enthusiasts is one in which only enough water is used to supply crop needs in addition to the unavoidable losses by direct evaporation from the soil.

Such rigid economy of water might be practicable if irrigation water were as pure as rain-water. But in view of the fact that irrigation water always contains salts and frequently contains large quantities, it is clearly a short-sighted policy to use so little water that the root zone is never leached.

It is probably not worthwhile to occupy your time with a detailed discussion of the kinds of salt that occur in irrigation water. There are many elements involved, and these may exist in a great variety of combinations. Our interest centers in the effect produced, either on the plants directly or on the physical conditions of the soil which in turn affect the plants. It does not appear from what we now know that our ordinary crop plants are much more sensitive to one combination of the more common salts than to another. If the soil solution is sufficiently dilute so that the plants can obtain the water they need, they are not much influenced by the character of the salts present. The essential thing is that the plants shall be able to take up the water fast enough to meet the requirements of transpiration and growth. The process of water absorption is interfered with when the concentration of the soil solution is high, almost without regard to the character of the salts in the solution. The point that is emphasized here is that in general the injurious effect of salts in the soil solution occurs by retarding the absorption of water by the plant roots rather than by any poisoning action within the plant. This distinction is important because it indicates how such injurious effects may be prevented.

When we recognize the fact that the soil solution must be kept dilute if our crop plants are to thrive, the way is open to prevent salt injury in irrigation. The salt that accumulates in the soil solution of the root zone is largely brought in by the irrigation water. The only known way to prevent that accumulation of salt is to leach the root zone from time to time and thus carry the salt away. An occasional leaching of the root zones appears to be essential, to successful irrigation farming. Unless this is done it is inevitable that in time the soil solution will become so concentrated with salt that the crop plants will be unable to obtain from it the water they need for normal growth.

It will be obvious that if the root zone is to be leached in order to reestablish a dilute solution by removing the accumulated salt, a way must be provided for the leaching water to escape. There are some areas of irrigated land so situated as to have adequate natural subsoil drainage. In general, however, it is found necessary to construct a system of artificial drains. In fact it is coming to be generally recognized that an adequate drainage system is essential to a tract of irrigated land.

In order to prevent the injurious accumulation of salt in the root zone of tlie soil, the method of irrigation should be such as to insure some leaching of the soil, at least occasionally. The frequency of leaching should be influenced by the quantity of salt in the irrigation water; if the quantity is large, the leachings should be more frequent. In other words the more salt there is in irrigation water the more copiously that water should be applied. I do not share the view that the need of drainage can be avoided by the economical use of irrigation water.

The point I wish to emphasize is this: The accumulation of salt in the soil solution of the root zones is one of the serious hazards in irrigation farming. It is preventable by the provision of adequate drainage and by following a method of irrigation that will insure effective soil leaching. We cannot avoid irrigation water that contains salt; but it is possibJe to operate an irrigation system in such a way that the injurious salts will be carried away by the drainage as rapidly as they are brought in by the irrigation water.

It Pays to Grow a Good Crop Rotation

Under proper management and where the soil, water, and climatic conditions are not unfavorable, the yield of the various crops produced under irrigation should be superior to those harvested where such conditions do not exist. But in eliminating the hazards of drought, which has long been recognized as an important limiting factor in securing large crop yields, and in taking advantage of an assured water supply, farmers assumed other responsibilities in connection with their operations which if not adequately met still endanger their success. A substantial proportion of the costs of crop production under irrigation are in the form of fixed charges which must be met regardless of the yield of the crop or even if there is a total crop failure. Thus, while the possibilities of securing larger per-acre returns are greater where the hazards of drought have been eliminated, the financial risks are correspondingly increased if the productivity of the soil is not so maintained that superior yields are assured.

Farmers producing crops under such conditions and confronted with increased operating costs are forced into a more intensive system of farming, because mediocre yields will not cover production costs and fixed charges. Such measures as summer fallowing, often resorted to advantageously in adjoining dry-land areas, are not practical. Because of the intensive cropping of the lands, which is an essential feature to success, unless a constructive farm program is practiced the productivity of the lands becomes more rapidly depleted and the ultimate consequences are more serious to the operators than is the case where the required standard of production is materially less. It is evident, therefore, that a successful agriculture under irrigated conditions is predicated upon the adoption of such a program of farm management that crop yields may be large enough to insure returns in excess of the fixed charges and other costs incident to their production. To attain this objective, a well-planned crop rotation program is now known to be an essential prerequisite.

I hold no brief that crop rotation by itself is the answer to the problem of sustained production. But I do strongly contend that crop rotation provides a most effective mechanism for the functioning of soil management leading to sustained production. In what follows I shall try to show you why I hold this opinion, and further what it is about a crop rotation that makes it either good or bad so far as its effect on the soil is concerned. I am not going to discuss the other values claimed for crop rotation, particularly as against continuous cropping, such as distribution of risks through diversification, more efficient use of labor, and reduced damage from weeds, insect, and crop diseases. We shall concern ourselves only with the effects of crop rotation upon productivity of the soil.

A high-quality sod-type legume, such as alfalfa, grown alone or in mixtures with clover and grass is of predominant importance in the crop rotation for the irrigated farm. To put soil in condition to grow such a crop successfully should be the initial objective of any soil improvement program.

I do not mean to imply that alfalfa has all good effects. No crop has all good or all bad effects on soil. All crops remove minerals from the soil unless the whole crop is plowed under. Actually, a good crop of alfalfa will remove more of all the mineral elements than correspondingly good crops of sugar beets, potatoes, or corn. But this does not mean we should quit growing alfalfa. It means, simply, that we are likely to have to add minerals to a cropping system containing alfalfa sooner than to one without it. This is well brought out in data from our Huntley, Mont., Field Station. During the second 6-year period following the establishment of the crop rotation experiments, beets grown continuously without treatment produced yields of 9 tons per acre, beets grown in 2- and 3-year rotations without alfalfa gave average yields of 10.5 tons per acre, beets grown in 4-year rotations with 2 years of alfalfa averaged 11.7 tons per acre, and where an additional year of alfalfa was added in a 6-year rotation beets averaged 13.5 tons per acre. During the fourth 6-year period the yields of beets were, respectively. 7.7, 6.7, 5.1, and 9.8 tons per acre. This represents a drop in yield per acre of 1.3 tons under continuous cropping, 3.8 tons in 2- and 3-year rotations without alfalfa,, 6.6 tons in 4-year rotations with 2 years of alfalfa, and 3.7 tons in 6-year rotations with 3 years of alfalfa. By way of comparison, beets grown in a 6-year 7-otation with 3 years of alfalfa but receiving manure also, produced yields of 16.7 tons per acre for this same fourth 6-year period.

In the second 6 years of this experiment soil nutrients were still at a high enough level to permit alfalfa without treatment to exert a beneficial effect on yields of beets. In the fourth 6-year period the level of nutrients was too low for alfalfa to function. These data do not condemn alfalfa, hut on the contrary they emphasizes the fact that machinery run at a faster rate requires more fuel. Both irrigation and alfalfa permit farming at a faster rate and if we are to take advantage of these potentialities we must adjust other management practices in line with the speed we wish to travel.

Jn an experiment at Huntley where alfalfa, manure, and fertilizers exert a combined influence on beet yields, the average production for the last 19 years has been 20.5 tons per acre. I could cite other data from both the humid and irrigated regions to show the beneficial effects of rotations over continuous cropping and of rotations with legumes over rotations without them, but I believe most of you are already familiar with these data. The evidence I have examined indicates a marked tendency for yields 1o decline when cultivated crops like corn, sugar beets, and potatoes are grown continuously, and a somewhat slower decline, all bough still notable, when the same crops are grown in rotation, unless the rotation includes a sod legume like clover or alfalfa.

I believe the most important reason that crop rotation including sod legumes is such a vital factor in maintaining soil fertility is that in such systems soil organic matter may be maintained. Where clean-cultivated crops are grown exclusively this is next to impossible by economic methods.

The explanation for these widely different effects of crops upon soil organic matter and nitrogen, I believe, lies in two important factors: (1) the amount of soil tillage required in growing the crop, and (2) the amount and composition of the root and stubble residues left by the crop. Organic matter is destroyed through the activity of bacteria and other microorganisms in the soil. The process is essentially one of oxidation and requires air, just like oxidation through combustion. Each time the soil is stirred, air is introduced into the soil and the rate of organic decomposition is speeded up. This probably explains why the destruction goes on so fast under corn and other intertilled crops. Willi the small grains the only tillage necessary is that given in preparing the seedbed, and with the hay crops as commonly grown no additional tillage is required beyond that given in preparing for the seeding of the companion crop.

Now let us turn to the matter of crop residues which determine how much accumulation of organic matter takes place. Before commenting on the individual crops it should be pointed out that the amount of humus left in the soil from the incorporation of equal weights of different kinds of residues varies considerably. Without taking time to explain why, it may be said that residues whose nitrogen content is low, such as those from corn and small-grain crops, disappear much more completely and leave relatively small amounts of humus compared to nitrogen-rich residues, such as those from alfalfa and sweet clover. For example in one experiment at Ohio State University equal weights of a number of different crop residues were incorporated with the soil. One of these was corn stover, low in nitrogen, another sweet clover, high in nitrogen. At the end of 1 year of active decomposition the amount of humus left, was in the case of corn stover only 17 percent of the weight of the stover added, whereas it was equal to 50 percent of the amount added in the case of sweet clover.

Here it might be interesting to cite a few figures showing the amounts of roots and nitrogen left in the soil after harvesting a few of the common crops as determined in some Ohio experiments.

Corn, 60-bushel yield. 800 pounds roots, 10 pounds nitrogen.

Soybean, 19-bushel yield, 550 pounds roots, 9 pounds nitrogen.

Red clover, 1.5 tons, 1,000 pounds roots, 22 pounds nitrogen.

Alfalfa, 3 tons yield, 3,900 pounds roots, 90 pounds nitrogen.

Alfalfa clover, at end of seeding year, 2,600 pounds roots, 96 pounds nitrogen.

From these figures it is easy to see why sod legumes are so effective in maintaining soil organic matter and nitrogen compared to such crops as corn and soybeans. Right along this line, it is interesting to point out that from soil studies made on some of the old fertility experiments in Ohio it was found that stable manure was twice as effective in maintaining soil organic matter and nitrogen when applied to a crop rotation including clover as it was when applied to continuous corn. Even chemical fertilizers carrying no organic matter have increased the amount of soil organic matter when applied to the small grain with which the clover was seeded. Apparently anything we do to a soil that results in better growth of the sod lgeumes is effective in keeping up the content of humus and nitrogen in the soil.

Now I want to point to some further advantages of sod legumes or legume-grass mixtures in the crop rotation. All farmers know what we mean by good soil tilth-that mellow, granular condition so favorable to the growth of most crops. We have in Ohio some very heavy clay soils where the maintenance of good physical conditions seems to be more important in obtaining high yields than supplying plant nutrients, with which these soils are naturally well supplied. When originally cleared these soils were fairly easy to drain and handle and they produced high yields. Forty to fifty years of cropping, chiefly to corn and oats, has left them seemingly much heavier, needing additional drainage, much more difficult to cultivate, and producing much lower crop yields. Laboratory studies show that, they have lost their original granular structure, contain much less pore space and are more impermeable to both air and water. In recent years it has been discovered that the best way to get these soils back into a healthy state is to introduce sod crops in the rotation. It appears that the fine fibrous roots of the legumes and grasses are peculiarly efficient in rebuilding these soils into a granular condition, while at the same time the deep-rooted legumes bore down through the heavy subsoil and leave channels through which water and air can move down to the tile lines.

1 believe that next to keeping the root zone free of excess quantities of injurious salts, the kind of crop rotation followed is the most important, factor in determining the trend in soil fertility on almost any irrigated farm.

It pays to take good care of manure and to apply it intelligently

The benefits of using farm manure in sugar beet production are too well-known and too well-appreciated to require much elaboration- Growing sugar beets without manure is like leaving the whiskey out of a highball. The kick just is not there.

The liquid is the most valuable part of manure. Plenty of bedding and tight floors in stables and manure pits diminish its loss. Heating losses of nitrogen and organic matter are best prevented by keeping the manure moist and well tramped. The most valuable part of the nitrogen is lost when the manure heats, dries out, or freezes. Such loss may take place after spreading on the field. Immediate plowing under after spreading is the only feasible method of prevention. It is impractical to prevent considerable loss of nitrogen from manure produced in warmer months. Such manure is best used by lop-dressing new meadow seedings or established alfalfa after the last cutting. Manure produced late in fall and in winter is best kept under good storage conditions and applied just before plowing for spring crops.

The value of a ton of manure in terms of increased yields in five rotation comparisons at our Scottsbluff Field Station ranged from $2.32 to $4.62 per ton, with an average value of $3.57 per ton for a 25-year period.

It pays to use chemical fertilizer generously

It seems to me that if there is one prejudice among western farmers it has to do with the use of commercial fertilizers. They have long boasted of their fertile soils and too many still believe that it is a reflection on their farming if they have to use fertilizers to maintain yields. This prejudice is gradually breaking down as is evidenced by the rapid increases in fertilizer consumption during recent years. The country as a whole used 7.4 percent more plant food in 1944 than in 1943, but in the western region the increase was 30.6 percent. When compared with the 5-year (1935-39) average, usage in 1944 was 243 percent of pre-war in the western region. This is marked progress, but I believe you have only begun to exploit the possibilities of using fertilizers in crop production under irrigation.

At the Utah Station in fertilizer tests over the last 12-year period, yields of sugar beets were increased an average of 42 percent by the addition of treble superphosphate, 72 percent by the addition of farm manure, and 83 percent by the addition of both manure and treble superphosphate. In other tests treble superphosphate increased alfalfa yields 2.G9 tons over the check plots, where the average yield was 2.76 tons per acre. As an average of 4 years' results, peach trees yields 308, 478, and 509 bushels per acre with no fertilizer. 3 pounds ammonium sulphate per tree, and 3 pounds each of ammonium sulphate and treble superphosphate per tree, respectively. This is an increase in production of more than 60 percent from nitrogen and phosphorus. At the Idaho Branch Station at Aberdeen, returns per dollar invested in phosphate applied to alfalfa averaged $7.73 for rates of treble superphosphate from 75 to 250 pounds per acre in 3 years, and $4.36 for rates from 300 to 900 pounds for acre in 3 years. When the increased yields of potatoes following the alfalfa were also considered, the returns per dollar invested in phosphate were $11.34 and $10.90, respectively.

I could cite more examples of profitable use of fertilizers under irrigation, but the point I want to emphasize is this: Under irrigation you have eliminated the hazard of drought and in so doing you have made possible a level of production far above that in our humid regions. To attain this level of potential production requires that other factors that may limit production also be eliminated. If the potential production is reached, plant nutrients will be removed from the soil at a more rapid rate than under humid agriculture. Thus, after an initial period of farming under irrigation, it will be necessary to apply larger quantities of fertilizer if yields are held at the high levels that are possible.

There is no argument of farm manure *versus* fertilizer. Use manure. Use all you have. But you do not have enough. And even where you have manure it often needs supplementing with either nitrogen or phosphorus and frequently both, if best results are to be obtained.

I should like to point out that intelligent use of fertilizers will require that other management practices be adjusted in keeping with the increase in plant nutrients. With higher levels of fertility we will want more plants per acre and we will use more water than was used in growing half of the potential crop.

It pays to follow a **complete program of soil management**

Highest efficiency in crop production is attained only when all elements of good soil management are used in combination and followed consistently. One-sided sporadic; attempts at soil management are only partially effective. Crop yields in the West could probably be increased 50 percent or more by the adoption of well-proved methods of soil management.