NEEDS:



# *Problems of Soil and Water*

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A CRITICAL NEED exists for research on soil and water in the Tropics and subtropics.

Although the basic growth requirements of plants related to soil and water are essentially the same throughout the world and few soil and water problems are unique to specific regions, problems of water shortage, degradation of quality of water, and salinity tend to be associated with arid climate. Problems of soil acidity and the fixation and leaching of nutrients are associated mainly with a humid climate. The maintenance of soil organic matter and nitrogen is most difficult in hot climates.

THE SUITABILITY of soils for cultivation depends strongly on the readiness with which they absorb and conduct water and air (permeability) and the ease with which they can be tilled (tilth). Supplying the water plants need, controlling drainage and salinity, and preventing erosion by water all require good soil permeability. Poor tilth adversely affects plant growth and makes necessary the use of more power in cultivation.

Because different kinds of minerals predominate in the soils, problems of poor permeability and tilth are most prevalent in dry temperate zones and least prevalent in humid zones.

Permeability and tilth tend to be

more favorable in sandy soils than in clayey soils but are determined mainly by the arrangement of soil particles.

High-clay soils, for example, may have excellent permeability and tilth if the particles are aggregated so as to form numerous large pores.

Conversely, the sandy soils may have poor permeability and tilth if their particles are dispersed so as to form small pores.

Soil scientists refer to the arrangement of soil particles as soil structure. Permeable soils that have good tilth have good structure.

A great deal remains to be learned about developing and maintaining good structure and about the nature of the surfaces of soil particles, the interaction of surfaces with water, the forces acting between particles, and the role of various materials in binding particles together.

Applied research has centered about the actions of organic matter, root growth, wetting and drying, and tillage operations in promoting a desirable structure.

Research on these actions must continue, but what is really needed to solve the problem of soil structure is the development of a cheap chemical compound that will bind particles into stable aggregates and be highly resistant to decomposition in the soil. Chemists have developed a number of such compounds, but their cost has prohibited their use except in special problems.

LONG AND INTENSIVE cultivation has depleted soil organic matter and nitrogen—the basic components of soil fertility—in many soils of the world. These components will decline in newly developed areas unless management practices that maintain them at their initial levels are adopted.

Soil organic matter helps maintain good soil structure, increases the capacity of soils to retain certain mineral nutrients, and contributes to the supply of nitrogen, phosphorus, and some of the minor elements.

We lack adequate information concerning the factors that affect the degree to which soil organic matter and nitrogen accumulate and are lost from the soil under various conditions of climate and environment, especially in humid tropical regions where the rates at which organic matter forms and decomposes may be high.

Because of the way in which it originates, soil organic matter has a complex and variable composition. Information is meager on the organic compounds present and the mode of their reaction with other soil constituents, such as clay.

Soil nitrogen is associated with soil organic matter because most of the nitrogen in the soil occurs in organic form. Nitrogen is added to the soil in the form of plant residues, by the fixation of atmospheric nitrogen, and to a limited degree in rainfall. It is lost through crop removal, erosion, leaching, and volatilization. That is the nitrogen cycle. Like organic matter, the rate of its accretion and depletion depends on soil type, the climate, and cropping system.

Research workers are attempting to evaluate more accurately the factors that affect the gains and losses of soil organic matter and nitrogen in order to explain some of the conditions observed in tropical regions. The conversion of nitrate and ammonium forms of nitrogen to gaseous nitrogen and the loss of gaseous nitrogen to the atmosphere are of particular interest because substantial amounts of nitrogen fertilizer are lost in this way.

Studies also have been undertaken to determine the effect of management practices on organic matter and the nitrogen levels. The information could be used to develop agricultural systems that permit the increase of soil organic matter in depleted soils and the maintenance of adequate levels in new land brought into cultivation.

LOSSES of soil and water from farmlands are serious in many countries, especially in humid regions and places where heavy, brief rains occur. Soil erosion greatly lowers soil fertility, raises the sediment burden of streams and rivers, and contributes to the silting up of waterways and storage facilities. As the land is taken out of native vegetation, the amount of runoff, loss of soil, and the dangers of floods all increase. In arid regions, protective measures also must be taken against wind erosion.

Preventive and corrective measures must be developed to meet the needs of the world's many agricultural systems.

Research therefore has been directed toward studies of the basic nature of soil erosion by wind and water, the relative erodibility of different soil types, and the effect of soil management practices on soil and water losses. The aim is to get new or to modify old systems in order to reduce soil and water losses.

Technicians of the Department of Agriculture have developed a way to predict the degree of soil erosion under various agricultural systems. New management practices are being developed that will improve areas already severely eroded.

Research in arid regions is directed toward a more efficient use of available rainfall as well as toward a reduction of soil losses.

LIMING ACID SOILS in temperate regions has been a common practice.

Reports from tropical areas indicate that crops there often do not respond to liming as they do in temperate regions and that a better understanding is needed as to why liming may be beneficial or have no effect or be detrimental on different soils.

Soil acidity has many direct and indirect effects on plant growth. Some acid soils contain toxic concentrations of soluble iron, aluminum, or manganese. Liming alleviates those toxicities. A nutritional deficiency of calcium or magnesium, or both, often is associated with soil acidity. An appropriate liming material corrects this condition.

Soil acidity also may govern to some degree the availability of major elements (such as phosphorus and potassium), the solubility of certain essential minor elements, and the types of soil micro-organisms, including those that fix nitrogen. Liming also may improve the structure of some soils.

We also want to know more about the role of aluminum in soil acidity and the nutritional requirements of plants for calcium and magnesium. All have a bearing on the development of more satisfactory methods of evaluating the amounts of lime soils need.

Because many acid soils in the Tropics do not respond to liming by standards developed for temperate regions, tropical soils must be classified and mapped, and their chemical and mineralogical characteristics must be determined so that the relation between soil acidity and plant responses to liming can be predicted better.

CHLOROSIS, a condition in plants characterized by a deficiency of chlorophyll and a yellow color, is one potential problem on almost one-third of the soils in the world. It usually is caused by a deficiency of iron and is associated generally with soils that naturally contain lime.

Iron deficiency, however, sometimes occurs in acid soils and in soils whose acidity has been reduced by liming. The problem is of economic importance, because the districts affected include many otherwise highly fertile soils and because the possibility of chlorosis restricts the choice of crops to those that are chlorosis-resistant.

Scientists do not understand fully the factors that affect the availability of iron in soils and the uptake of iron by plants. Besides the low content of iron and the presence of lime, bicarbonates in soil or in irrigation water, waterlogging, and poor soil aeration frequently are contributory causes of chlorotic conditions in plants.

Iron deficiency may also be induced in plants by deficiencies of potassium, calcium, and magnesium and by high levels of manganese, copper, zinc, molybdenum, cobalt, nitrogen, and phosphorus. Chlorosis in plants may result from any one or a combination of these conditions.

Investigations of the various causative factors in the soil and in the plant have as their goal the development of diagnostic techniques and remedial measures, such as newer and more effective chelating agents designed to make iron more readily available in both sprays and fertilizer formulations.

Trace elements, which plants need in tiny amounts, can harm plants if they occur in concentrations not greatly exceeding the optimum amounts.

Physiological disturbances of plants may result from inadequate or excessive concentrations of boron, zinc, molybdenum, manganese, and copper. In some instances, plants may not be affected, but animals that eat them may suffer physiological disorders.

An increase in soil acidity causes an increase in the availability of zinc, copper, boron, and manganese. Sometimes liming acid soils will increase plant response to molybdenum.

In some countries, such as Australia and New Zealand, spectacular increases in crop production have been obtained by applications of only a few pounds of trace elements per acre.

The identification of areas where deficiencies of minor elements exist has become a great need. Research in some of the lesser developed countries indicates that potential deficiencies of trace elements may be widespread but are masked by low levels of fertility.

As crop yields in those areas increase, the deficiencies must be corrected. New diagnostic techniques and survey procedures are being developed to facilitate this, and new fertilizer formulations and chelating agents are being developed as corrective measures.

In places where it is hard to maintain an adequate level of plant nutrients in soils and where fertilizer is greatly needed but is costly and scarce, adequate information has to be provided to permit the most efficient utilization of available fertilizers. Therefore, the most economic rates and methods of application and ways to cut losses due to leaching and irreversible fixation in the soil must be determined.

The efficient use of applied nutrients depends on a correct evaluation of the needs of a given crop on a given soil. Soil-testing procedures have been developed, but they must be correlated with plant response under different soil and environmental conditions if they are to be most effective. This type of information is lacking in many underdeveloped areas.

Serious losses of native and applied nutrients result from excessive leaching of water through soils, especially in the more humid areas. Ways to reduce leaching losses by varying the time, rate, and method of fertilizer application and to determine the proper combination of soil and fertilizer material are being studied. New fertilizer materials are being developed that dissolve slowly and thereby reduce the amount of nutrient subject to leaching at any given time.

Irreversible fixation in forms not available to plants accounts for large losses of mineral nutrients applied to soils. The problem is widespread and is particularly serious in humid tropical soils. Phosphorous fertilizers are fixed as insoluble iron and aluminum phosphates in acid soils and as an insoluble tricalcium phosphate in alkaline soils.

Research workers seek to evaluate various phosphorous mechanisms of fixation. The findings are utilized to develop management practices that will help make the use of phosphorous fertilizer more efficient.

Of the estimated 49 million cubic miles of water in the world, about 3.2 million cubic miles, or less than 7 percent, is fresh. With a world population of approximately 3 billion people, the amount of fresh water per person is more than 1,200 million gallons.

Only a small fraction of the fresh

water is available for man's use, however. About 28 percent occurs as polar ice and glaciers; about 70 percent is underground, mostly at depths that make extraction costly; and 1 percent is in lakes and rivers.

Because the water in lakes and rivers and underground must be recharged for continuous use, the world's total water resource—disregarding the possibility of desalinating sea water—is essentially the annual precipitation, which is small in relation to total fresh water, being approximately 25,500 cubic miles.

South America, which is the most humid continent, receives a mean annual precipitation of 53 inches.

North America, Europe, Asia, and Africa each has a mean annual precipitation of about 25 inches.

In Australia it is 18 inches.

The percentage of precipitation that runs off into rivers is of special significance from the standpoint of water available for irrigation and domestic and municipal uses. This percentage varies from 36 to 39 for North America, South America, Europe, and Asia but is only 23 and 11 for Africa and Australia, respectively.

Estimates of the percentage of annual runoff utilized for domestic, industrial, and agricultural purposes are not available by continents, but for the United States the value was 19 in 1950. It is estimated that the percentage will increase to 36 by 1975 and to nearly 60 by the year 2000.

While annual runoff in world rivers amounts to about 3 million gallons per person, local water shortages are becoming widespread because the distribution of precipitation is not uniform and the cost of transporting water great distances is high.

One means of alleviating water shortages for agriculture is by developing water conservation practices. Considerable amounts of water are lost through evaporation from soil and from water surfaces. Soil scientists constantly are seeking improved tillage and mulching methods for reducing evaporation from soil. The application of plastic films and various chemicals to soil surfaces for evaporation suppression is also under investigation.

A significant advance in reducing evaporation from ponds and reservoirs is the discovery that the application of certain organic compounds to water surfaces in amounts sufficient to form a film one molecular layer thick reduces evaporation up to 30 percent.

Growing plants transpire enormous amounts of water—up to 800 pounds of water per pound of dry matter produced in Temperate Zones. The ratio of water used to dry matter produced may be even higher in tropical zones. It is not surprising, then, that scientists throughout the world are seeking ways to reduce transpiration without affecting growth adversely.

Research in Israel and Australia centers around the application of various chemicals to plant leaves to close partly the stomata, the small openings through which most water leaves the plant. Stomata are also the pathway by which carbon dioxide for photosynthesis enters the plant. A basic research problem is how to manipulate the opening and closing of stomata so as to reduce transpiration without causing a deficiency of carbon dioxide for photosynthesis and growth.

Not all plant growth is beneficial. Weeds and woody growth in stream channels waste water. Research is underway to find better ways to eliminate this undesirable plant growth.

Another water conservation measure under study consists of treating or covering the surface of soil-supporting nonbeneficial vegetation with materials that increase runoff which may be collected for beneficial use elsewhere.

In Arizona, for example, it has been found that surface treatments involving spraying an asphalt emulsion on cleared shrub lands causes nearly complete runoff. In Utah, ground covers and storage bags of artificial rubber have proved practical for supplying water to rangeland livestock.

Reduction of seepage losses from

earthen conveyance channels and more efficient application of water to fields in irrigated areas result in marked savings of water.

Much research is in progress to develop low-cost materials and methods for sealing earthen conveyance channels, including lining them with clay and plastic film and treatment with organic compounds that tend to seal soil surfaces.

Much research has been conducted on more efficient methods for applying irrigation water, but the adoption of improved methods depends on costs and labor. Research on sprinkler irrigation, an effective way to conserve water, is largely concerned with more uniform distribution of water and automation to lessen labor costs.

It is becoming evident that, even with the adoption of stringent water conservation measures, there will be places in the world where shortages of water will occur. Interest is great therefore in the development of low-cost methods for desalinating brackish and sea water.

Intensive research on the subject is in progress at many places in the United States and in other countries.

We know at least six processes for removing salt from water. The cost of some processes, such as distillation, is essentially independent of the salt content of the water, but the cost of other processes, such as electrodialysis, is strongly dependent on salt content. Thus the choice of a process may be different for brackish water than for sea water. Research centers on ways to increase efficiency and lower costs.

Except in special cases, the present cost of desalinated water is too great for use in producing food and fiber. This becomes especially evident when one considers that the present cost of irrigation water is largely for distribution. Industries and municipalities undoubtedly will become users of desalted water before agriculture because they can afford to pay a higher price. But nobody knows how cheap the cost of desalination may eventually become through research. Enormous nuclear-powered distillation plants producing electricity as a byproduct may yet make desalinated water practical for agriculture.

FROM THE STANDPOINT of meeting world agricultural needs, the problem of removing excess water from soil is perhaps as important as that of water shortages.

Excess water in soil interferes with plant growth, tillage, and harvesting and normally results from a water table that is near the soil surface.

In humid regions and in arid areas where irrigation is practiced, artificial drainage is often essential for high crop yields. Many countries have large areas of waterlogged but potentially good cropland that can be reclaimed by artificial drainage. Artificial drainage is accomplished by constructing ditches, installing tile lines at depths in the soil, or by pumping from wells.

The drainage requirements of soils often are expressed as the permissible depth of the water table beneath the soil surface. In humid regions where the ground water is essentially salt free, the permissible depth is largely determined by that required to obtain adequate soil aeration. On the other hand, the permissible depth in irrigated areas is largely dictated by that required to control soil salinity. Salts in the irrigation water and in the ground water usually increase the drainage requirement.

A minimum allowable water-table depth that will permit adequate leaching and that will prevent concentration of salts in the root zone by upward flow must be established. Thus information on the rate of upward flow in soils of various types as a function of depth to water table is necessary for determining the drainage requirements. Considerable research on this subject has been undertaken.

Great advances in drainage techniques have been made through increased knowledge of the principles governing the flow of water through soils and the application of mathematics to flow problems.

Soil permeability largely determines the required depth and spacing of drains. Good field methods have been developed for determining the permeability of soil beneath the water table, but scientists are still seeking adequate methods for measuring the permeability of soil above the water table.

Another remaining problem, one that complicates the overall evaluation of soil permeability for the installation of drains, is how to take into account differences in the permeability of different soil layers and also differences in vertical and horizontal permeability within layers.

Scientists have found that the flow of electricity in an electric conductor resembles the flow of water in soil. Voltage corresponds to the force causing water movement, electrical resistance corresponds to soil permeability, and amperage corresponds to rate of water flow. Thus electric models of drainage problems can be built and tested, and the results can be interpreted in terms of water flow instead of electric current. Additional research on the application of this technique to practical drainage problems is needed.

The installation of drainage systems, especially tile drains, is costly. Tile is made of fired clay or cement and installed by digging trenches to the desired depth. Conduits of plastics and other materials are also in use or under development.

In some areas, tiling machines dig the trench, lay the tile, and backfill more or less in one operation. In much of the world, though, most tile is laid by hand, sometimes with the aid of simple machines. Drainage would be greatly facilitated by the development of cheaper tiling materials that could be installed by simple machines. In-place casting of concrete has been tried in England.

Research has been started in the United States on the use of perforated plastic mole drain lines, which are installed behind a shoe drawn through the soil at the desired depth.

WHEN RAINFALL is too scant for crops, many countries depend on irrigation, an ancient practice on which several once-flourishing civilizations were based. Their decline has led some persons to question the permanence of irrigation agriculture.

From the standpoint of permanence, the main difference between irrigated and nonirrigated agriculture arises from salinity. Rain is essentially salt free, but water for irrigation may contain several hundred pounds or even several tons of dissolved salt per million gallons. Plants in irrigated fields absorb the water but leave nearly all the salt behind in the soil, where it accumulates and eventually prevents plant growth unless it is leached out.

The accumulation of salt has caused the abandonment of much formerly productive soil and has undoubtedly contributed to the failure of civilizations. We have learned enough about the cause, prevention, and cure of salinity, however, so we can say with some certainty that irrigation agriculture can be permanent.

Irrigation projects usually are on suitable land near rivers. Plants use most of the applied water and return it to the atmosphere through transpiration. Some is lost by evaporation, however, and some leaches through the soil and becomes drainage water. The water that drains from a project contains nearly all the salt initially in the water diverted to the project; when it returns to the river, the salinity of the river increases. Thus the increased use of water for irrigation means that the salt content of many streams in arid regions is growing.

Increases in the salt content of irrigation water make salinity control in soils more complex and difficult. To meet this problem, we have sought more information on soil, water, and crop management for salinity control and better ways to evaluate and use saline waters.

Growing salt-tolerant crops is one way to utilize saline irrigation waters. Plant scientists at the United States Salinity Laboratory are attempting to learn the mechanism of salt injury to plants and the physiological basis of salt tolerance. We hope such information will make possible the development of crop varieties having superior salt tolerance.

The possibility of using brackish waters for supplemental irrigation in humid coastal areas also is being investigated. Here the leaching action of winter rainfall prevents the accumulation of salt in the soil and permits the use of waters having salt concentrations higher than the ones recommended for arid regions.

Some irrigation waters contain a high proportion of sodium, which reacts with the soil and causes it to have poor permeability and tilth. Procedures are needed for predicting whether soils will accumulate harmful amounts of sodium from irrigation waters. Attempts are being made to improve present procedures for waters containing high amounts of bicarbonate as well as sodium and to develop cheaper and more effective methods for reclaiming soils that have become unproductive by the accumulation of sodium. Such soils have been reclaimed by the application of gypsum or sulfur.

Experiments have indicated that some types of sodium-affected soil can be reclaimed by plowing to depths of 3 or 4 feet. Others can be reclaimed by leaching with otherwise useless saline drainage water progressively diluted with irrigation water of good quality.

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# *Research in Forestry*

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Research in forestry has spread from its beginnings in the 19th century in central Europe to the far corners of the world.

Research institutes are of two broad classes. Some are engaged primarily in research on timber growing: Reproducing the forest crop; improving it by application of principles of genetics; protecting it from fire, insects, and disease; thinning and making improvement cuttings; and integrating timber growing with wildlife propagation, the grazing of domestic livestock, and recreation. At some institutes, research in principles of watershed management related to forest and grass cover also is conducted.

Research at other stations is devoted primarily to the utilization of forest products—the technical properties of wood of various species, improved methods of using them in the manufacture of various finished products, ways of increasing the serviceability of wood, and economical ways of integrating the use of the forest for a combination of products requiring various qualities of wood in such a way that the maximum economic return is obtained with a minimum of actual waste of wood.

Research is conducted also at many universities, sometimes in cooperation with experiment stations.

Some research is done by private