STUDYING WATER, SALT AND NUTRIENT MOVEMENT IN NORTH DAKOTA SOILS

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In recent years soil physics, soil classification, and soil characterization specialists in the Soil Science Department have cooperated in numerous studies relating to nutrient, salt, and water movement in North Dakota soils. Primary motivations for this research direction have been the need for scientific investigations of public concerns about possible adverse accumulation of nutrients in the environment and awareness that efficient use of fertilizer materials and management of soil salinity are important aspects of planning for profitable production. Our purpose in this article is to outline past accomplishments and to give a more detailed picture of our present efforts.

PAST RESEARCH

Measurement of basic soil hydraulic properties is important for a good understanding of water movement and storage in soil. Cassel and Sweeney (1974) evaluated water holding capacities of several soil types at 28 North Dakota sites ranging in texture from clay loam to loamy sand. Cassel (1974) later conducted unsaturated hydraulic conductivity tests on 11 of the same sites. Carvallo et al. (1976) conducted a study of how the unsaturated hydraulic conductivity of Maddock sandy loam changes from point to point in a field. These studies have created a valuable data base necessary for future modeling of soil water flow and storage.

Direct evaluations of water and solute movement were conducted by Cassel (1971) and later by others (Bauder and Schneider, 1979; Bauder and Montgomery, 1979). Recommendations arising from these studies included avoidance of fall-applied nitrate-containing fertilizers on well drained sandy soils.

Interrelationships of soil and water are of great importance in irrigation and several studies have addressed this topic. An early study (Schroer, 1970; Oster and Schroer, 1979) examined the influence of different compositions of irrigation water on physical and chemical properties of certain North Dakota soils. Later, water quality standards were published for sprinkler irrigation of various soils (Schroer and Bauer, 1977). The use of waste water for irrigation was also studied (Funke and Schroer, 1973; Schroer, 1979).

Three recently published reports addressed a variety of aspects of the overall water, salt and nutrienty movement question. Lang and Prunty (1983) reported on movement of nutrients with eroded sediment in a laboratory study of mineland topsoils. Improvement of sodic soils (Hussin, 1982) by use of amendments and leaching was the topic of a laboratory study using soil columns obtained with minimal disturbance of the natural soil structure. A site-specific study of subsurface hydrology was conducted by Shay and Sweeney (1982) to better define natural water flow patterns and the topography of strata restricting drainage.

Leaching of nitrates in coarse-textured soils under irrigation has been the subject of a five-year study at Oakes. A preliminary report on part of this work has already been presented (Montgomery and Prunty, 1982) and the remainder of the data are under analysis at the present time.

PRESENT EFFORTS

Lysimeter research

A new thrust in research on nutrient and water loss due to drainage from an irrigated soil was started in 1980 through funding provided jointly by the Garrison Diversion Conservancy District and the U.S. Bureau of Reclamation. Four drainage-type lysimeters, large containers filled with soil and buried so that the soil surface of the lysimeter is indistinguishable from the surrounding soil, were installed near Oakes (Fig. 1). Direct measurement of water and nutrients that percolate below the root zone of irrigated crops is the primary purpose of these lysimeters. Such subsurface irrigation return flows have been an environmental concern with respect to irrigation in North Dakota and elsewhere. In order to best simulate a soil profile in an area of extensive irrigation, the bottoms of the lysimeters were designed for maintaining a water-table condition. In contrast to the weighing lysimeters used in climatic research, these lysimeters are not useful for directly measuring short-term evapotranspiration. Evapotranspiration can be estimated on a long-term basis using water balance techniques however.

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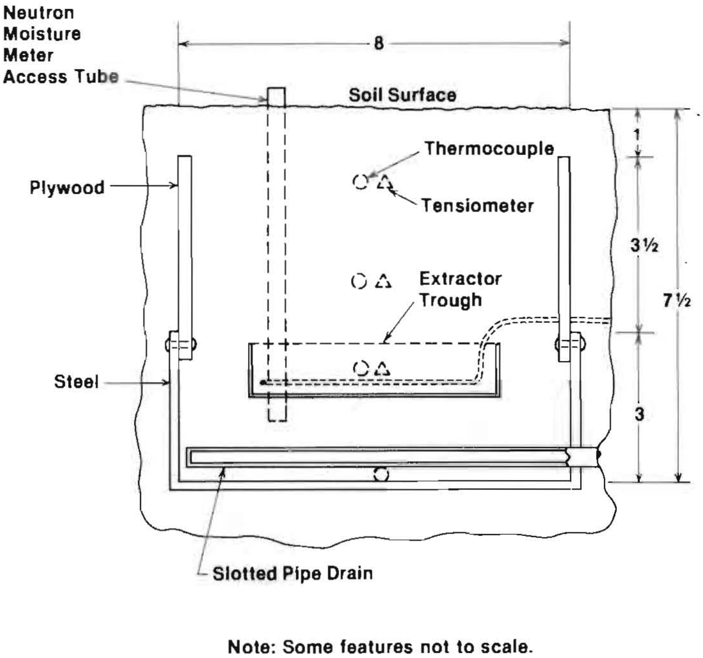

Figure 1. Cross section of one lysimeter as installed at Oakes. Water passing below the root zone of the crop is drained from the lysimeter by the slotted drain pipe. The water then flows by gravity to the control structure where the flow rate is measured and samples are obtained for chemical analysis.

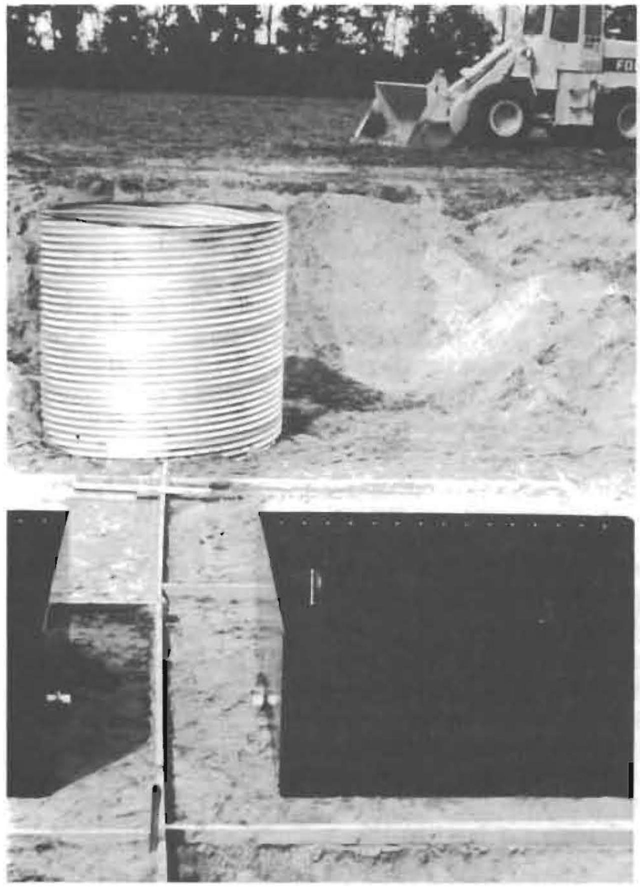

Figure 3. The bottom portion of two lysimeter tanks are in the foreground and the vertical corrugated culvert to be used as a control structure is shown in the background. The lysimeters and excavation shown were subsequently refilled with a Hecla soil profile. The present soil surface is at about the same level as the top end of the culvert, which is now covered with a roof and access hatch. USBR Photo.

Construction of the lysimeter facility started in August 1980 with excavation of about 500 cubic yards of soil from the site (Fig. 2). Along with construction of the lysimeters themselves, an underground "control structure" was provided so that the drainage water could be measured and sampled. This structure consisted of an 8-foot diameter corrugated steel culvert standing on end (Fig. 3). The lysimeters were carefully refilled with soil while at the same time installing tensiometers to measure the status of the soil water and thermocouples to measure soil temperature. One "extractor trough" was also installed within 2 feet of the bottom of each lysimeter.

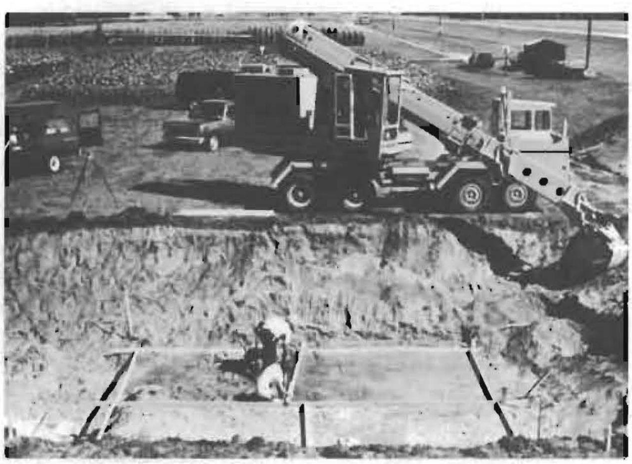

Figure 2. Excavaton of area for installation of lysimeters. Lysimeter tanks were placed on smoothed base shown being created here. The excavating machine shown belongs to the U.S. Bureau of Reclamation. The Oakes Irrigation Field Trials site is in the background.

The basic construction and refilling of the lysimeters was completed in October 1980. The recording of flow volumes and collecting of samples was started in May 1981; the facility has operated continuously since then. Presenty, water quality samples are collected three times weekly. Chemical parameters of the drain water samples analyzed include N (as nitrate and ammonium), P (as orthophosphate), chloride, sulfate, carbonate, bicarbonate, calcium, magnesium, sodium, potassium and pH. Soil temperatures at four depths in each lysimeter are measured and recorded three times weekly. Soil moisture is monitored by neutron moisture meter and tensiometer. Irrigated corn was grown on the lysimeters and the surrounding plot in 1981 and 1982 and has again been planted in 1983. Dr. Earl Stegman of the Agricultural Engineering Department is supplying irrigation scheduling recommendations weekly during the irrigation season.

Data from the lysimeter system are voluminous and a summary will not be attempted here. We can say, however, that in many respects the lysimeter sytem has performed up to or exceeded our expectations. The data will provide valuable information regarding percolation of nutrients, particularly nitrogen, and water below the root zone of crops. With only four lysimeters available, only two management options can be compared by means of replicated experiments , however. This means that in the near future the lysimeter system will be valuable mainly in obtaining good estimates of actual water and nutrient movement for a few management systems that have greatest importance for nitrogen management or are the most likely to actually be used with irrigation in the Oakes area. We now also have the experience in construction and operation of lysimeters that should enable prompt expansion of the number of lysimeters when and if the need arises.

Greenhouse study of irrigation water-soil compatibility

A study was recenty completed using four soils irrigated with seven qualities of irrigation water to grow alfalfa in the greenhouse. The alfalfa was grown for approximately 24 months in the 112 undisturbed cylinders of Svea, Barnes, Roseglen and Max soils. Although analysis of the data is preliminary, it is apparent that water quality strongly influenced growth of the alfalfa. This study is important because it will help us learn about changes in the soils caused by irrigation with various qualities of water. The soil series used are among the slowly permeable soils that are likely to be developed for irrigation.

Effect of sustained irrigation on selected soil properties

Soil profiles from approximately 50 sites are being sampled periodically to determine changes in chemical and physical properties due to irrigation with water of differing quality. Results of soil samplings to date show an increase in soil salinity in the upper [soil] horizons of the soil profile to a level approaching the salinity of the water applied. Physical changes, such as surface crusting and additional power required for tillage, have been noted at some sites where the irrigation water has an elevated sodium content. As more data are compiled from field, greenhouse, and laboratory studies, criteria for successful sustained irrigation will be more fully developed.

Water analysis for irrigation

Water to be used for irrigation is analyzed for inorganic chemical constituents in the soil characterization laboratory at NDSU. Recommendations for the use of water for irrigation are based on the water quality and the kind of soil to be irrigated. An irrigation guide (SCS, 1978) has been prepared for use in North Dakota by trained technicians to provide planning and design assistance in the preparation of technically sound irrigation plans and the use of conservation measures on irrigated lands. All recommendations for irrigation are based on the most recent data obtainable, and additions and refinements will be made as more technical material is made available.

Irrwter Computer Program

Water quality analyses from over 800 groundwater sites throughout North Dakota are being compiled for computer recall and analysis. Each site is identified by legal description, year of sampling, well depth, inorganic chemical constituents and the soils to be irrigated. The data will be used to identify potential soil-water compatibility problem areas. The State Water Commission will use the data for refining their ongoing characterization of groundwater aquifers throughout the state.

Characterization of the natural condition of soil salinization

A synthesis of the natural conditions in the state which determine the actual and potential processes of soil salinization is of primary importance. These studies involve the summation of the published data about salinity of the rivers, lakes, groundwater, shallow groundwater, and salt-affected soils in the state and the collection of some data which were not previously available.

The salinity of river waters is one of the best expressions of the salinity condition of an area. The total salinity of about 7000 river water samples has been related to their anion and cation composition. Eight general patterns of salt accumulation in river waters have been established; these are related to the specific natural conditions in the basins of the rivers. These conditions include the geology of the basin, the salinity of the aquifers, the geomorphology and the climate (Maianu, 1983). Based on the stages of salt accumulation that are specific to the eight groups of rivers, a genetic classification of river waters has been proposed. The groups are divided into stages of salt accumulation according to characteristic changes in salt composition with increasing total salinity.

The anionic composition and SAR values may be estimated inexpensively by knowing the specific group of the water along with its electrical conductivity value. Finally, a more precise classification of river waters for irrigation in North Dakota can be established taking into consideration not only EC and SAR values, as is usually done, but also the stages of salt accumulation in the river waters (Maianu, 1983).

A similar study has been done for the main aquifers of North Dakota. Their chemical composition has been characterized in relationship with the geology of the aquifers. The total salinity of North Dakota aquifers ranged from a minimum of 6.8 to a maximum of 87,027 micromho per centimeter. The aquifers of the Holecene epoch are high in salt content, rich in sulfates and have a moderate SAR. The aquifers of the Pleistocene epoch are usually high in sulfates. The Paleocene aquifers are very saline, sulfatic and have a high SAR, due to the marine influence.

Nine groups of aquifers have been identified in the state. Each group has a specific anion or group of anions that accumulate continuously with increased total salinity, is characterized by specific rates of anionic accumulation, and has a particular range of SAR values (Maianu, 1981).

The accumulation of salt has also been studied in the lakes of North Dakota because they may constitute a source of water for irrigation. The available data from 78 lakes show that 51 percent of the lake waters present a medium hazard for soil salinity and 38 percent of them have a high salinity hazard. More than 50 percent of the waters have a low sodium hazard and the rest have a very high sodium hazard.

With regard to trace elements, some lake waters have to be tested for lithium, boron, manganese, molybdenum and fluorine. These trace elements have the potential of being at toxic levels in the Devils Lake Basin. For some sensitive crops such as potatoes, cadmium may be excessive in some waters (Maianu, 1983).

Very few data are available about the salinity of the shallow groundwaters in the state. Because they directly influence the soil salinization process, such data are essential to determine the contribution of groundwaters to the salt balance of different soil series. The present effort is directed to the collection of such necessary data.

Salt tolerance of the major crops

The salt tolerance of hard red spring wheat has been determined for the Red River Valley (Maianu, 1982), and research is in progress for determining salt tolerance for sunflowers, soybeans and pinto beans. Starting in 1983, a larger number of crop swill be studied for salt tolerance at the Langdon Experiment Station. The research permits the establishment of indices which characterize the salt tolerance of the major crops in North Dakota. Yields of hard red spring wheat are not influenced by soil salinity up to 5.5 milimho per centimeter. A yield of 50 percent below the normal may be obtained at a soil salinity of 11.6 milimho per centimeter. Finally, at a salinity of 18.0 milimho per centimeter yields are essentially zero.

Knowing these characteristic values for every crop, farmers can decide which crops to grow, and have an estimate of the probable yield that they may expect.

Reclamation methods and management practices on salt-affected soils

Four representative series of salt-affected soils have been selected for an extensive experiment on their reclamation by amendment application and leaching. They are Ojata silty clay, Bearden silty clay loam, Averson fine sandy loam, and Stirum fine sandy loam.

The soils have been packed in PVC cylinders in the greenhouse and eight to nine treatments have been applied. The process of salt leaching has been studied by determining the concentration of each anion and cation in the drainage water collected at regular intervals.

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