Soil, Water and Plant Characteristics Important to Irrigation

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Thomas F. Scherer, Extension Agricultural Engineer
Bruce Seelig, Extension Water Quality Specialist
David Franzen, Extension Soils Specialist

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Irrigation, applying water to assure sufficient soil moisture is available for good plant growth, as practiced in North Dakota is called "supplemental irrigation" because it is used to augment the rainfall that occurs during the growing season. Irrigation is used on full season agronomic crops to provide a dependable yield every year. It is also used on crops where water stress affects the quality of the yield, such as flowers, vegetables and fruits.

During most years it is not uncommon for some places in the state to receive sufficient rainfall for good plant growth while other areas experience reduced yields or quality on non-irrigated crops because of water stress from insufficient soil moisture. For irrigation planning purposes, average precipitation during the growing season is not a good yardstick for determining a need for irrigation. The timing and amounts of rainfall during the season, the soil's ability to hold water, and the crop's water requirements are all factors which influence the need for irrigation. Any location in the state can have what might be considered "wet" or "dry" weeks, months and even years.

Under irrigation, soil and water compatibility is very important. If they are not compatible, the applied irrigation water could have an adverse effect on the chemical and physical properties of the soil. Determining the suitability of land for irrigation requires a thorough evaluation of the soil properties, the topography of the land within the field and the quality of water to be used for irrigation. A basic understanding of soil/water/plant interactions will help irrigators efficiently manage their crops, soils, irrigation systems and water supplies.

Soil Properties

Soil surveys of every county in North Dakota have been completed by the Natural Resource Conservation Service (NRCS, formerly the SCS). The county soil survey report provides detailed soils information on any parcel of land and is available from the county NRCS office or the NDSU Department of Soil Science. The soil properties of texture, structure, depth, permeability and chemistry play an important role in irrigation management.

Soil Texture

Soil texture is determined by the size and type of solid particles that make up the soil. Soil particles may be either mineral or organic. In most soils, the largest proportion of particles are mineral and are referred to as "mineral soils." For mineral soils, the texture is based on the relative proportion of the particles under 2 millimeters (mm) or 5/64th of an inch in size. As shown in Figure 1, the largest particles are sand, the smallest are clay, and silt is in between. The soil texture is based on the percentage of sand, silt and clay (Figure 2). Soil texture classes may be modified if greater than 15% of the particles are organic (e.g. mucky silt loam). Soil particles greater than 2 mm in size are not used to determine soil texture. However, when they make up more than 15% of the soil volume, the textural class is modified (e.g. gravelly sand).

Soil texture can be determined by separating and weighing the sand, silt and clay. For example, if a 100 pound sample of soil was sifted through screens and found to contain 45 pounds of sand, 35 pounds of silt and 20 pounds of clay, then the soil would be composed of 45% sand, 35% silt and 20% clay. As shown by the dotted lines in Figure 2, this soil has a loam texture. There are 12 basic soil textures shown on Figure 2. Sand, loamy sands and sandy loams are the most common soil textures irrigated in North Dakota.

Soil Structure

Soil structure refers to the grouping of particles of sand, silt, and clay into larger aggregates of various sizes and shapes. The processes of root penetration, wetting and drying cycles, freezing and thawing, and animal activity combined with inorganic and organic cementing agents produce soil structure (Figure 3). Structural aggregates that are resistant to physical stress are important to the maintenance of soil tilth and productivity. Practices such as excessive cultivation or tillage of wet soils disrupt aggregates and accelerate the loss of organic matter, causing decreased aggregate stability.

The movement of air, water, and plant roots through a soil is affected by soil structure. Stable aggregates result in a network of soil pores that allow rapid exchange of air and water with plant roots. Plant growth depends on rapid rates of exchange. Good soil structure can be maintained by practicing beneficial soil management such as crop rotations, organic matter additions, and timely tillage practices. In sandy soils, aggregate stability is often difficult to maintain due to low organic matter, clay content and resistance of sand particles to cementing processes.

Soil Series

Soil is the layer of the earth's surface which has been changed by physical or biological processes. The five soil-forming factors that control the process of change are parent material, climate, topography, biota (plants and animals) and time. Soils are grouped into categories according to their observed properties. The USDA classification system consists of six categories. The highest category (soil order) contains 11 basic soil groups, each with a very broad range of properties. The lowest category (soil series) contains over 12,000 soils, each defining a very narrow range in soil properties.

North Dakota has 264 soil series. A soil series is unique because of a combination of properties such as texture, structure, topographic position (on the side of a hill or in a valley) or depth to the water table. A particular soil series describes locations where these soil conditions are similar. These locations may be in the same field, section, county, state or even region. Soil delineations on county soil survey maps are based on the soil series. A soil series is generally named after a town near the site that represents the typical properties for that soil. For example, the site with typical properties for the Embden soil series is near Embden, North Dakota.

Many soil series do not have a deep, uniform soil profile. Restrictive subsurface layers often interfere with root penetration. In these situations the roots will be concentrated in the upper part of the soil profile. For example, in the Renshaw loam profile (Figure 4), the majority of the plant roots will be in the top 18 inches because of the poor growing environment encountered in the underlying sand and gravel substrata. This type of information is important for irrigation management.

Soil Depth

Soil depth refers to the thickness of the soil materials which provide structural support, nutrients, and water for plants. In North Dakota, soil series that have bedrock between 10 and 20 inches from the surface are described as shallow. Bedrock between 20 and 40 inches is described as moderately deep. Most soil series in North Dakota have bedrock at depths greater than 40 inches and are described as deep. Depth to contrasting textures is given in the soil series descriptions in the county soil survey report.

The depth to a contrasting soil layer of sand and gravel (Figure 4) can affect irrigation management decisions. If the depth to this layer is less than 3 feet, the rooting depth and available soil water for plants is decreased. Soils with less available water for plants require more frequent irrigations.

Soil Permeability and Infiltration

A soil's permeability is a measure of the ability of air and water to move through it. Permeability is influenced by the size, shape, and continuity of the pore spaces, which in turn are dependent on the soil bulk density, structure and texture. Most soil series are assigned to a single permeability class based on the most restrictive layer in the upper 5 feet of the soil profile (Table 1). However, soil series with contrasting textures in the soil profile are assigned to more than one permeability class. In most cases, soils with a slow, very slow, rapid or very rapid permeability classification are considered poor for irrigation.

Table 1. Soil Permeability Classes.

Classification	Infiltration Rate (inches/hour)
Very Slow	Less than 0.06
Slow	0.06 to 0.2
Moderately Slow	0.2 to 0.6
Moderate	0.6 to 2.0
Moderately Rapid	2.0 to 6.0
Rapid	6.0 to 20.0
Very Rapid	Greater than 20.0

Infiltration is the downward flow of water from the surface through the soil. The *infiltration rate* (sometimes called intake rate) of a soil is a measure of its ability to absorb an amount of rain or irrigation water over a given time period. It is commonly expressed in inches per hour. It is dependent on the permeability of the surface soil, moisture content of the soil and surface conditions such as roughness (tillage and plant residue), slope, and plant cover.

Coarse textured soils such as sands and gravel usually have high infiltration rates. The infiltration rates of medium and fine textured soils such as loams, silts, and clays are lower than those of coarse textured soils and more dependant on the stability of the soil aggregates. Water and plant nutrient losses may be greater on coarse textured soils, so the timing and quantity of chemical and water applications is particularly critical on these soils.

Saline and Sodic Soils

Salt affected soils are grouped according to their content of soluble salts and sodium (Table 2). Saline and sodic soils usually occur in areas where ground water moves upward from a shallow water table close to the soil surface. The water carries salts which accumulate in the soil as the water is evaporated from the soil surface or transpired through the plants to the atmosphere. **In general, these soils are not recommended for irrigation.**

Table 2. Soil chemistry measurements used to classify saline, sodic and saline-sodic soils.

	Electrical Conductivity*	Sodium Adsorption Ratio*

	(mmhos/cm)	pH	(SAR)
Saline soil	greater than 4	less than 8.5	less than 13
Sodic soil	less than 4	8.5 to 10	greater than 13
Saline-Sodic soil	greater than 4	less than 8.5	greater than 13

*Measured from a saturated soil extract

Saline and sodic soils may be of natural or man-made origins. One of the man-made processes is related to irrigation. Under certain combinations of irrigation water quality and soils, salts and/or sodium may accumulate in the root zone and have an adverse effect on plant growth.

Under some conditions, *sodium* can be controlled in the upper part of the soil through the use of calcium amendments. The replacement of sodium by calcium improves the structure of the soil. Calcium soil amendments can be helpful in situations where land with a majority of unaffected irrigable soils contains pockets (inclusions) of sodium affected soils. Under irrigation, calcium soil amendments will help where surface crusting has become a problem. Special irrigation management practices may be required on these soils.

Salt concentrations can be managed by leaching or controlling the water table elevation. Leaching is accomplished by applying more water than the soil will hold within the root zone. Large rainfall events, applying additional irrigation water or both will carry some of the salts below the root zone. Water table control can be accomplished by planting a deep rooted crop, such as alfalfa, or installing subsurface drainage. Deep ditches and tiling are methods of subsurface drainage that have been used successfully to control the level of the water table in many parts of the world.

Soil salt and sodium contents need to be measured to precisely determine the severity of the problem. The salt content of the soil is estimated from an electrical conductivity measurement using a soil water extract, soil water slurry or soil paste. The sodium content of the soil is often measured on a soil water extract and expressed as the ratio between the sodium and calcium plus magnesium and given the term **sodium adsorption ratio (SAR)**.

Soils can be monitored by soil sampling the surface layer (top 6 inches) on a periodic basis (every three to five years). The SAR of the soil samples will indicate if there is a buildup of sodium. Generally, soils with an SAR of 13 from the saturated extract will exhibit significant physical problems due to dispersal of clay particles. Usually a soil with an SAR of 6 or lower from the saturated extract will not have physical problems associated with dispersed clay. However, if periodic sampling indicates that the SAR is increasing, say from 6 to 9, then it may be time to consider corrective action.

Topography of the Field

Topography or the "lay of the land" has a large impact on whether a field can be irrigated. Relief is a component of topography that refers to the difference in height between the hills and depressions in the field. The topographic relief will affect the type of irrigation system to be used, the water conveyance system (ditches or pipes), drainage requirements and water erosion control practices. The shape and arrangement of topographic landforms and the type of surface waterway network will also influence irrigation management.

Slope

Slope is important to soil formation and management because of its influence on runoff, soil drainage, erosion, use of machinery, and choice of crops. Slope is the incline or gradient of a surface and is commonly expressed in percent. The percent slope is determined by measuring the difference in vertical elevation in feet over 100 feet of horizontal distance. For example, a 5 percent slope rises or falls 5 feet per 100 feet of horizontal distance.

In addition to the percent of slope, the shape of the slope is another important characteristic. A convex slope curves outward like the outside surface of a ball, a concave slope curves inward like the inside surface of a saucer, and a plane slope is like a tilted flat surface.

Slopes are described as simple or complex. Simple slopes have a smooth appearance with surfaces extending in one or perhaps two directions. For example, slopes on alluvial fans and foot slopes of river valleys are regarded as simple. Complex areas have short slopes which extend in several directions and consist of convex and concave slopes much like the knoll and pothole topography found on glacial till plains.

Simple slopes of 1% or less are commonly used for gravity (surface) irrigation. Simple and complex slopes greater than 1% should only be irrigated with sprinkler or drip systems. Center pivot sprinkler irrigation systems can operate on slopes up to 15%, but simple slopes greater than 9% are not generally recommended.

To accommodate an irrigation application method such as gravity or sprinkler systems, the slope in a field can be modified by land smoothing. However, land smoothing may cause yield reductions for one to three growing seasons. The places where topsoil was removed are most likely to have yield reductions. Special management of these areas through increased fertilizer and organic matter applications may be required for accelerated recovery.

Irrigation Water Quality

The quality of some water is not suitable for irrigating crops. Irrigation water must be compatible with both the crops and soils to which it will be applied. The Soil and Water Environmental Laboratory in the NDSU soil science department provides soil and water compatibility recommendations for irrigation. Generally a water analysis and a legal description of the land proposed for irrigation are required before a recommendation can be made.

The quality of water for irrigation purposes is determined by its salt content. An analysis of water for irrigation should include the *cations*: calcium, magnesium, and sodium, and the *anions*: bicarbonate, carbonate, sulfate, and chloride. Some crops are sensitive to boron, so it is often included in the analysis.

Irrigation Water Classification

The two most important factors to look for in an irrigation water quality analysis are the **Total Dissolved Solids (TDS)** and the **Sodium Adsorption Ratio (SAR)**. The TDS of a water sample is a measure of the concentration of soluble salts in a water sample and is commonly referred to as the *salinity* of the water. TDS is expressed in terms of the electrical conductivity (EC) and its units are either:

millimhos per centimeter (mmhos/cm),
deci-Siemens per meter (dS/m) or
micromhos per centimeter (mmhos/cm)

where:

1000 mmhos/cm = 1 mmho/cm = 1 dS/m

The SAR of a water sample is the proportion of sodium relative to calcium and magnesium. Since it is a ratio, the SAR has no units.

Laboratories that perform irrigation water analysis may provide a suitability classification based on a system developed at the U.S. Salinity Laboratory in California (Figure 5). This classification system combines salinity and sodicity. For example, a water sample classified as C3-S2 would have a high salinity rating and a medium sodium rating. The scale for sodicity is not constant because it depends on the level of salinity. For example, an SAR of 8 is in the S1 category if the salinity is from 100 to 300 mmhos/cm; S2 if the salinity is from 300 to 3000 mmhos/cm, and S3 if the salinity is greater than 3000 mmhos/cm.

Much of the water in North Dakota is classified in the C2 to C3 salinity range and the S1 to S2 sodium hazard range. **In general, any water with an EC greater than 2000 mmhos/cm or an SAR value greater than 6 is not recommended for continuous irrigation in North Dakota.** In cases where sporadic irrigation is practiced (i.e. a particular piece of land is only irrigated one year out of three or more), lower quality water may be used. However, the lower quality water should not have an EC that exceeds 3000 mmhos/cm or an SAR greater than 10.

Calcium added to irrigation water can lower the SAR and reduce the harmful effects of sodium. The effectiveness of added calcium depends on its solubility in the irrigation water. Calcium solubility is controlled by both the source of the calcium (e.g. calcium carbonate, gypsum, calcium chloride) and also the concentration of other ions in the irrigation water. Compared to calcium carbonate and gypsum, calcium chloride additions will result in higher concentrations of soluble calcium and be the most effective at lowering irrigation water SAR. However, calcium chloride is considerably more expensive than calcium carbonate and calcium sulfate (gypsum).

Carbonates

Carbonate and bicarbonate ions in the water combine with calcium and magnesium to form compounds which precipitate out of solution. Removing calcium and magnesium increases the sodium hazard to the soil from irrigation water. The increased sodium hazard is often expressed as "adjusted SAR." The increase of "adjusted SAR" over the SAR is a relative indication of the increase in sodium hazard due to the presence of these ions.

Precipitation of carbonate minerals has not been observed to plug sprinkler systems in North Dakota, but these minerals can cause plugging in drip irrigation systems. To control this problem, the pH of the irrigation water is generally lowered by adding a mild acid.

Salinity

C1 - Low salinity water -- can be used for irrigation with most crops on most soils with little likelihood that soil salinity will develop. Some leaching is required, but this occurs under normal irrigation practices except in soils of slow and very slow permeability.

C2 - Medium salinity water -- can be used if a moderate amount of leaching occurs. In most cases plants with moderate salt tolerance can be grown without special practices for salinity control.

C3 - High salinity water -- cannot be used on soils with moderately slow to very slow permeability. Even with adequate permeability, special management for salinity control may be required and plants with good salt tolerance should be selected.

C4 - Very high salinity water -- is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The soils must have rapid permeability, drainage must be adequate, irrigation water must be applied in excess to provide considerable leaching, and very salt tolerant crops should be selected.

Sodium

S1 - Low sodium water -- can be used for irrigation on almost all soils with little danger of development of harmful levels of exchangeable sodium.

S2 - Medium sodium water -- will present an appreciable sodium hazard in fine textured soils, especially under low leaching conditions. This water may be used on coarse textured soils with moderately rapid to very rapid permeability.

S3 - High sodium water -- will produce harmful levels of exchangeable sodium in most soils and requires special soil management, good drainage, high leaching, and high organic matter additions.

S4 - Very high sodium water -- is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity.

Boron

Boron is essential for the normal growth of all plants, but the quantity required is very small. Plants sensitive to boron, such as dry beans, require much smaller amounts than plants that are tolerant of boron, such as corn, potatoes and alfalfa. In fact, the concentration of boron that will injure the sensitive plants is often close to that required for normal growth of tolerant plants.

Although there have been no documented problems with boron in water used for irrigation in North Dakota, testing for this element in irrigation water is a precautionary practice. Boron does occur in some North Dakota ground water at concentrations that are theoretically toxic to some crops. Boron concentration greater than 2 parts per million (ppm) may be a problem for certain sensitive crops, especially in years that require large quantities of irrigation water.

The Interaction Between Soil and Water

Soil is a medium that stores and moves water. If a cubic foot of a typical silt loam topsoil were separated into its component parts, about 45% of the volume would be mineral matter (soil particles), organic residue would occupy about 5% of the volume, and the rest would be *pore space*. The pore space is the voids between soil particles and is occupied by either air or water. The quantity and size of the pore spaces are determined by the soil's texture, bulk density and structure.

Water is held in soil in two ways: as a thin coating on the outside of soil particles and in the pore spaces. Soil water in the pore spaces can be divided into two different forms: gravitational water and capillary water (Figure 6). Gravitational water generally moves quickly downward in the soil due to the force of gravity. Capillary water is the most important for crop production because it is held by soil particles against the force of gravity.

As water infiltrates into a soil, the pore spaces fill with water. As the pores are filled, water moves through the soil by gravity and capillary forces. Water movement continues downward until a balance is reached between the capillary forces and the force of gravity. Water is pulled around soil particles and through small pore spaces in any direction by capillary forces. When capillary forces move water from a shallow water table upward, salts may precipitate and concentrate in the soil as water is removed by plants and evaporation.

Water Holding Capacity of Soils

There are four important levels of soil moisture content that reflect the availability of water in the soil. These levels are commonly referred to as: 1) saturation, 2) field capacity, 3) wilting point and 4) oven dry.

When a soil is saturated, the soil pores are filled with water and nearly all of the air in the soil has been displaced by water. The water held in the soil between saturation and field capacity is gravitational water. Frequently, gravitational water will take a few days to drain through the soil profile and some can be absorbed by roots of plants.

Field capacity is defined as the level of soil moisture left in the soil after drainage of the gravitational water (Figure 7). Water held between field capacity and the wilting point is available for plant use.

The wilting point is defined as the soil moisture content where most plants cannot exert enough force to remove water from small pores in the soil. Most crops will be permanently damaged if the soil moisture content is allowed to reach the wilting point. In many cases, yield reductions may occur long before this point is reached.

Capillary water held in the soil beyond the wilting point can only be removed by evaporation. When soil is dried in an oven, nearly all water is removed. "Oven dry" moisture content is used to provide a reference for measuring the other three soil moisture contents.

When discussing the water holding capacity associated with a particular soil series, the water available for plant use in the *root zone* is commonly given (Table 3). Available soil water content is commonly expressed as inches per foot of soil. For example, the water available can be calculated for a soil with fine sandy loam in the first foot, loamy sand in the second foot and sand in the third foot. The top foot would have about 2.0 inches, the second foot would have about 1.0 inch and the third foot would have about 0.75 inches for a total of 3.75 inches of available water for a crop with a 3 foot root depth.

Table 3. Available Soil Moisture Holding Capacity for Various Soil Textures.

	Available Soil Moisture	
Soil Texture	inches/inch	inches/foot
Coarse Sand and Gravel	0.02 to 0.06	0.2 to 0.7
Sands	0.04 to 0.09	0.5 to 1.1
Loamy Sands	0.06 to 0.12	0.7 to 1.4
Sandy Loams	0.11 to 0.15	1.3 to 1.8
Fine Sandy Loams	0.14 to 0.18	1.7 to 2.2
Loams and Silt Loams	0.17 to 0.23	2.0 to 2.8
Clay Loams and Silty Clay Loams	0.14 to 0.21	1.7 to 2.5
Silty Clays and Clays	0.13 to 0.18	1.6 to 2.2

Soil Moisture Tension

The degree to which water clings to the soil is the most important soil water characteristic to a growing plant. This concept is often expressed as soil moisture tension. Soil moisture tension is negative pressure and commonly expressed in units of *bars*. During this discussion, when soil moisture tension becomes more negative it will be referred to as "increasing" in value. Thus, as soil moisture tension increases (the soil water pressure becomes more negative), the amount of energy exerted by a plant to remove the water from the soil must also increase. One bar of soil moisture tension is nearly equivalent to -1 atmosphere of pressure (1 atmosphere of pressure is equal to 14.7 pounds per square inch at sea level).

A soil that is saturated has a soil moisture tension of about 0.001 bars, or less, which requires little energy for a plant to pull water away from the soil. At field capacity most soils have a soil moisture tension between 0.05 and 0.33 bars. Soils classified as sandy may have field capacity tensions around 0.10 bars, while clayey soil will have field capacity at a tension around 0.33 bars. At field capacity it is relatively easy for a plant to remove water from the soil.

The wilting point is reached when the maximum energy exerted by a plant is equal to the tension with which the soil holds the water. For most agronomic crops this is about 15 bars of soil moisture tension. To put this in perspective, the wilting point of some desert plants has been measured between 50 and 60 bars of soil moisture tension.

The presence of high amounts of soluble salts in the soil reduces the amount of water available to plants. As salts increase in soil water, the energy expended by a plant to extract water must also increase, even though the soil moisture tension remains the same. In essence, salts decrease the total available water in the soil profile.

How Plants Get Water From Soil

Water is essential for plant growth. Without enough water, normal plant functions are disturbed, and the plant gradually wilts, stops growing, and dies. Plants are most susceptible to damage from water deficiency during the vegetative and reproductive stages of growth. Also, many plants are most sensitive to salinity during the germination and seedling growth stages.

Most of the water that enters the plant roots does not stay in the plant. Less than 1% of the water withdrawn by the plant is actually used in photosynthesis (i.e. assimilated by the plant). The rest of the water moves to the leaf surfaces where it transpires (evaporates) to the atmosphere. The rate at which a plant takes up water is controlled by its physical characteristics, the atmosphere and soil environment.

As water moves from the soil, into the roots, through the stem, into the leaves and through the leaf stomata to the air, it moves from a low water tension to a high water tension (Figure 8). The water tension in the air is related to its relative humidity and is always greater than the water tension in the soil.

Plants can extract only the soil water that is in contact with their roots. For most agronomic crops, the root distribution in a deep uniform soil is concentrated near the soil surface (Figure 9). Over the course of a growing season, plants generally extract more water from the upper part of their root zone than from the lower part.

Plants such as grasses, with a high root density per unit of soil volume, may be able to absorb all available soil water. Other plants, such as vegetables, with a low root density, may not be able to obtain as much water from an equal volume of the same soil. Vegetables are generally more sensitive to water stress than high root density agronomic crops such as alfalfa, corn, wheat and sunflower.

Crop Water Use

Crop water use, also called evapotranspiration or ET, is an estimate of the amount of water transpired by the plants and the amount of evaporation from the soil surface around the plants. A plant's water use changes with a predictable pattern from germination to maturity. All agronomic crops have a similar water use pattern (Figure 10). However, crop water use can change from growing season to growing season due to changes in climatic variables (air temperature, amount of sunlight, humidity, wind) and soil differences between fields (root depth, soil water holding capacities, texture, structure, etc.).

Many years of research have produced a number of equations that allow accurate estimates of crop water use values to be calculated from measured daily weather variables. Accurate estimates of crop water use values can be calculated for all the major irrigated crops in North Dakota.

Knowledge of water use patterns during the different growth stages has a major influence on how an irrigation system is designed and managed. Failure to recognize the water use patterns of a crop may result in poorly managed water applications. Crop water stress, fertilizer and pesticide leaching and increased pumping costs are just a few of the results of poor irrigation water management.

Irrigation Water Management

Obtaining increased yield from irrigation requires appropriate management of all the inputs. This means fertilizing to meet the yield goal, good tillage practices and efficient management of the amount of applied water. One of the most difficult parts of irrigation management is deciding when to turn on the irrigation system and how much water to apply. Fortunately, irrigation scheduling methods to help make those decisions have been developed.

Using rational or scientific methods to schedule irrigations is essential for good irrigation management, especially in North Dakota where irrigation is used to supplement rain. Good irrigation management begins with accurate measurement of the rain received on each irrigated field and knowing the soil moisture status in each field at the start of the vegetative growth stage. Over the years, a number of scheduling methods have been developed. Measurement of soil moisture levels has been the most common method of irrigation scheduling, but newer methods use a combination of crop water use and soil water estimates.

The oldest and most commonly used irrigation scheduling method is the "feel method," which estimates soil moisture by taking a soil sample in hand and squeezing it into a ball, observing the appearance of the ball and creating a ribbon of soil between the thumb and forefinger to estimate the soil moisture content. This method requires practice and experience to become accurate at predicting irrigation water needs. It is popular because it can be combined with other field activities such as scouting for insects, soil sampling for nitrogen, petiole sampling, etc.

More accurate soil moisture measurement methods use mechanical devices such as tensiometers and soil moisture blocks for irrigation scheduling. These devices are particularly helpful with fruit and vegetable crops and have proven to be accurate, reliable and inexpensive. Other more sophisticated instrumentation can be used for irrigation scheduling but generally are not used for irrigation management because of the expense.

An irrigation scheduling procedure called the "checkbook" method has been used successfully for many years in North Dakota. The checkbook method is a soil moisture accounting method which uses crop water use values and soil water holding capacities to predict the time to irrigate and amount of water needed to replenish what has been removed from the root zone.

North Dakota has a number of automated weather stations which record weather data on an hourly basis. This system is called the North Dakota Agricultural Weather Network (NDAWN). The weather data collected at each station allows calculation of accurate estimates of crop water use values on a daily basis. The crop water use estimates for several crops are available electronically (bulletin board) for each weather station on the NDAWN system and can be used with the checkbook method. This new technology now provides a way to access site-specific estimates of crop water use values.

Additional Sources of Information

Extension Publications

Soil Survey Bulletin (EB-60)
Managing Saline Soils in North Dakota (SF-1087)
Salinity and Sodicity in North Dakota Soils (EB-57)
Introduction to Irrigation... A Checklist (AE-92)
Selecting a Sprinkler Irrigation System (AE-91)
Irrigation Scheduling by the Checkbook Method (AE-792)
Extension Irrigation Handbook
Compatibility of North Dakota Soils to Irrigation from Surface and Groundwater Sources

NRCS Publications

North Dakota Irrigation Guide
County Soil Survey Reports

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North Dakota State University Agriculture and University Extension
Dept. 7070, Morrill 7, P.O. Box 6050, Fargo, ND 58108-6050