SOIL AND WATER CHARACTERISTICS IMPORTANT IN IRRIGATION

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INTRODUCTION

Irrigation is the application of water to soil to assure that sufficient moisture is available for good plant growth. In many areas of the arid southwest, water supplied by irrigation is the only moisture a crop receives, while in more humid areas water is supplied by irrigation only during dry periods. This latter situation applies to North Dakota where the addition of water by irrigation is supplementary to normal precipitation. In some years the state, as a whole, receives sufficient rainfall for high level crop production, but it is not unusual in some years that many crops suffer in some degree from inadequate moisture. Long time precipitation averages are misleading, because any given location in the state can have wet and dry months as well as wet and dry years.

When determining the suitability of land for irrigation, a more thorough evaluation of the soil, drainage, and topography are needed than when planning for dryland farming. Quality of irrigation water is also important. Therefore the farm operator needs a complete inventory and evaluation of the above factors when considering irrigation.

SOIL DEPTH

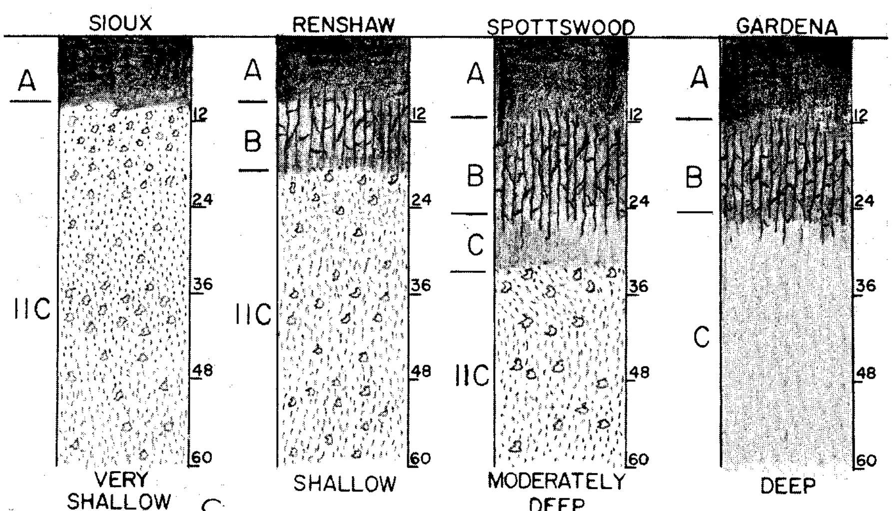
Soil depth refers to the thickness of soil materials which provides support for plants. In some areas of North Dakota this material is underlain at varying depths by sand, gravel, or bedrock, which provides little or no support for the plant. Table 1 presents the soil depth classes used when making standard soil surveys. Figure 1 presents diagrams of some soil series in the depth classes.

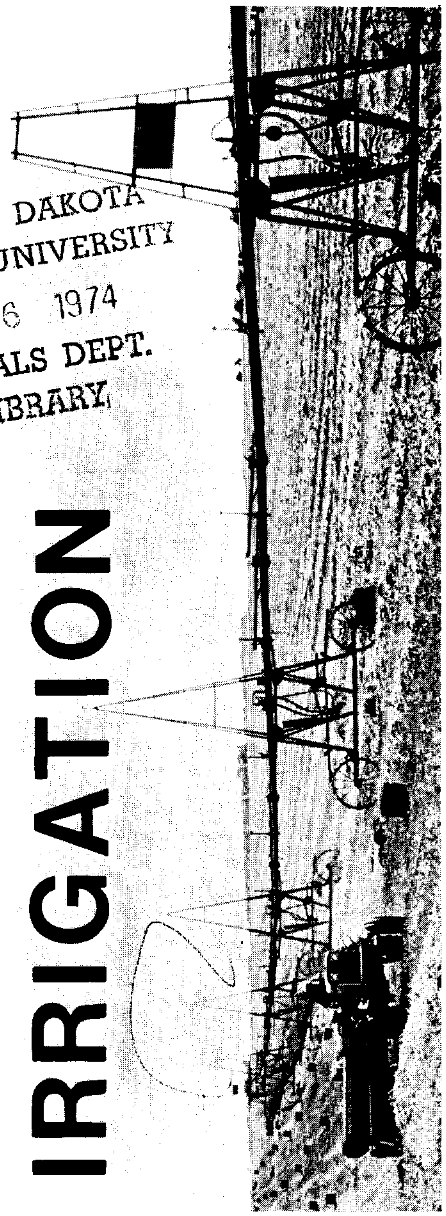
Table 1. Soil Depth Classes (7)

Depth	Depth Class
0 to 10 inches	very shallow
10 to 20 inches	shallow
20 to 40 inches	moderately deep
40 to 60 inches	deep

The depth of soil is important not only because of the amount of available water it stores but also for determining the rooting depth of plants. Shallow soils have low available water capacities and require more frequent irrigations than moderately deep or deep soils. Water and plant nutrient losses due to leaching are more likely to occur as a result of applying more water than the soils are capable of holding.

Figure 1. Soil Profile Diagrams





IRRIGATION

SOIL TEXTURE

Soil texture refers to the relative proportions of sand, silt, and clay size particles in a given soil. It influences, to a large extent, the amount of available water and plant nutrients a soil can store. Table 2 presents size limits of soil particles. Table 3 presents the soil textural classes.

The amount of water stored by a soil increases with silt and clay content. Table 4 presents approximate available water holding capacity information for various textural classes.

For most cases, a soil which holds less than 3 inches of available water in the upper 4 feet of soil is considered to be a poor irrigation risk. An example of the calculations used for determining the available water holding capacity of a soil, using the data in Table 4, follows. A Renshaw loam soil consists of 18 inches of loam textured soil material overlying coarse sand and gravel.

Thickness (inches)	Material	Available Water Holding Capacities (Inches of Water Per Inch of Soil)	Total Inches of Available Water
18	loam	.17 to .22	3.06 to 3.96
30	coarse sand and gravel	.02 to .05	.60 to 1.50
48			3.66 to 5.46

Table 2. Soil Particle Size Limits (4)

Soil Particle Name	Diameter Limits (mm)	Particles Per Inch
Gravel	Greater than 2.0	Less than 15
Very coarse sand	2.0 to 1.0	12 to 25
Coarse sand	1.0 to 0.50	25 to 50
Medium sand	0.50 to 0.25	50 to 100
Fine sand	0.25 to 0.10	100 to 250
Very fine sand	0.10 to 0.05	250 to 500
Silt	0.05 to 0.002	500 to 12,500
Clay	Less than 0.002	More than 12,500

Table 3. Soil Textural Classes (7)

Texture	Textural Class
Sands Loamy sands	Coarse
Sandy loam Fine sandy loam	Moderately coarse
Very fine sandy loam Loam Silt loam	Medium
Clay loam Silty clay loam	Moderately fine
Silty clay Clay	Fine

Table 4. Approximate Available Water Holding Capacities for Various Textural Classes (unpublished data)

Texture Class	Available Water Holding Capacities, inches of water per inch of soil
Coarse sand and gravel	.02 to .06
Sands	.04 to .09
Loamy sands	.06 to .12
Sandy loams	.11 to .15
Fine sandy loams	.14 to .18
Loams and silt loams	.17 to .23
Clay loams and silty clay loams	.14 to .21
Silty clays and clays	.13 to .18

Referring to the example of Renshaw loam the top 18 inches of soil material in this soil profile supports the majority of the plant roots since the roots would not penetrate the sand and gravel; so therefore this soil would be considered marginal for irrigation since only 3.06 to 3.96 inches of water would be available for plant growth.

The available water holding capacity of a soil influences the frequency of irrigation, soils having low water holding capacities requiring more frequent applications of irrigation water. The more often irrigation is required the greater the cost of water application with some irrigation systems. The amount of water utilized by the crop grown and its depth of rooting must also be considered when evaluating a soil for irrigation.

SOIL STRUCTURE

Soil structure refers to the arrangement of sand, silt, and clay size particles into aggregates of various sizes and shapes, and the stability or durability of these aggregates.

Figure 2 presents the various types of soil structure described during a standard soil survey.

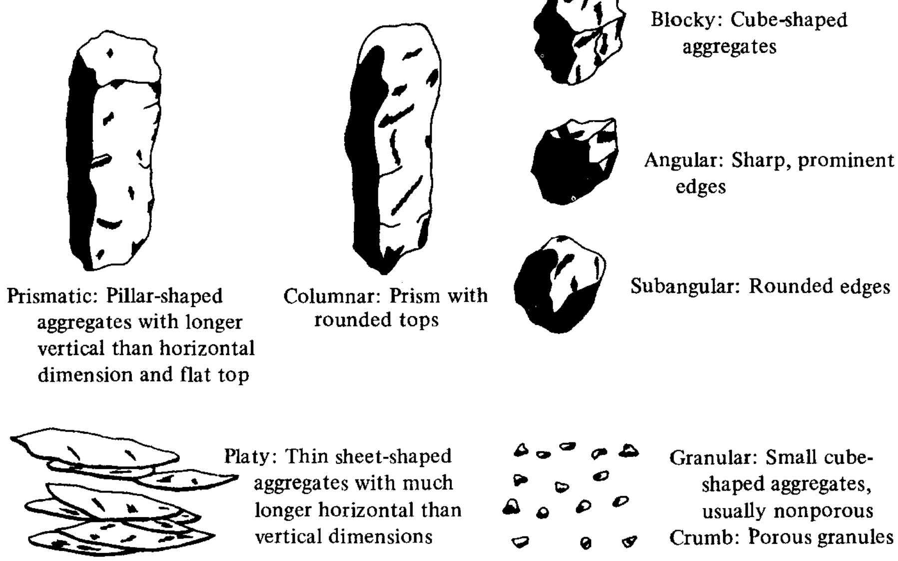
The movement of air, water, and plant roots through a soil is dependent to a large extent on soil structure. Soils formed of aggregates that disintegrate readily in water require careful management. Generally, tillage of dry soil tends to destroy the structure, whereas tillage of wet soil may result in a puddled soil condition.

INFILTRATION RATE

The infiltration rate of soils is closely related to soil structure and texture. The rate at which water enters the soil surface is determined to a large extent by the stability of the aggregates at the surface, especially their water stability. Good structure can be maintained by proper soil management practices, including crop rotations, organic matter additions, and timely tillage practices.

Coarse and moderately coarse textured soils usually have high infiltration rates while the rate for medium, moderately fine, and fine textured soils depends to a large extent on the aggregate stability. As soil moisture content increases, the infiltration rate decreases except for soils having high proportions of sand and gravel and

Figure 2. Types of Soil Structure (11)



which have high intake rates. Sprinkler methods of water application for soils with high intake rates are usually recommended.

SOIL PERMEABILITY

Soil permeability is the rate at which the soil transmits water and air. It is determined to a large extent by the size and shape of the pore spaces and the density of the soil, which in turn is dependent on the soil structure and texture. Water that is not retained by the soil should drain freely. Table 5 presents soil permeability classes which are a measure of the percolation rate of water through a soil profile. (7)

Table 5. Soil Permeability Classes

Percolation Rate Inches/Hour	Class
Less than 0.06	Very slow
0.06 to 0.20	Slow
0.20 to 0.60	Moderately slow
0.60 to 2.00	Moderate
2.00 to 6.30	Moderately rapid
6.30 to 20.00	Rapid
Greater than 20.00	Very rapid

Very rapid or rapid permeability are characteristic of coarse textured soils. Moderately coarse textured soils have moderately rapid permeability; medium textured soils have moderate or moderately slow permeability; moderately fine textured soils have moderately slow or slow permeability; and fine textured soils have slow or very slow permeability. Occasionally, an exception to the above generalization is observed.

Loss of applied water and excessive leaching of plant nutrients with possible contamination of the ground water could occur with excessive irrigation of a soil having rapid or very rapid permeability. At the other extreme, a soil having slow or very slow permeability has restricted downward movement of water which results in a waterlogged condition, in which the pore spaces are filled with water. Some soils have a dense layer beneath the surface which restricts free drainage of water and creates a perched water table. In most cases, a soil with a permeability class of slow or very slow having a percolation rate of less than 0.2 inches per hour is considered a poor irrigation risk.

Farm operators considering irrigation of medium and moderately fine textured soils should obtain an "on site" evaluation by qualified personnel. At the present time the application of water to soils formed in glacial till is not recommended because of the lack of permeability data.

SOIL SALINITY-ALKALINITY

"Saline soils" refer to those soils which contain a sufficient amount of soluble salts to adversely affect plant growth. "Alkali soils" refer to those soils which contain an amount of exchangeable sodium, either with or without appreciable amounts of soluble salts, which adversely affect plant growth. Soils containing excessive amounts of sodium have poor physical condition.

Salt affected soils are grouped according to their content of soluble salts, exchangeable sodium, or both. These groups are saline, alkali, and saline-alkali soils. Several soil properties are determined to properly group salt affected soils. The salt content of the soil is estimated from an electrical conductivity measurement on a saturated soil paste or an extract from the soil paste. The degree of acidity or alkalinity of a soil is expressed by the pH value. The relative amount of exchangeable-sodium (ESP) in a soil is expressed as a percentage of the cation-exchange-capacity.

Saline soils have a conductivity of the saturation extract greater than 4 millimhos per centimeter, the pH of the saturated-soil paste is usually less than 8.5, and the exchangeable sodium percentage is less than 15.

Alkali soils have a conductivity of the saturation extract less than 4 millimhos per centimeter, the pH of the saturated-soil paste usually ranges between 8.5 and 10.0, and the exchangeable-sodium percentage is greater than 15.

Saline-alkali soils have a conductivity of the saturation extract greater than 4 millimhos per centimeter, the pH of the saturated-soil paste is variable but is usually less than 8.5, and the exchangeable-sodium percentage is greater than 15.

Saline, alkali or saline-alkali soils usually occur in areas where the ground water contains a high concentration of salts and the water table is close to the soil surface. These salts accumulate in the soil as a result of water evaporation and water uptake by plants. It is therefore essential to lower the water table below the root zone of the crop grown. In order to remove excess salts from the soil, additional water must be applied to leach the soluble salts from the root zone. Good permeability and internal drainage are essential for adequate leaching. Subsurface drains are often required.

Reclaiming alkali soils involves not only leaching the excess soluble salts, but replacing the sodium salts with calcium salts if sufficient calcium is not present. The replacement of sodium by calcium improves the physical properties of the soil. Failure to recognize the need for special management practices in saline and alkali soil areas may result in low crop production or even crop failure. Soil management practices useful in these areas include selection of salt-tolerant crops, special irrigation and tillage practices, and the use of soil amendments, such as gypsum, if sufficient calcium is not present, or sulfur if sufficient calcium is present. A word of caution: the use of amendments may be impractical because of the costs involved.

DRAINAGE

Another important consideration in irrigation planning is to provide adequate drainage both on the land surface and within the soil profile. On many soils, drainage is necessary to remove excess water and to control the level of the water table below the root zone of the crop grown. Excess water in the root zone restricts root growth and delays warming of the soil in the spring. The water table must be kept deep enough to allow water to drain out of the rooting zone and thus prevent the accumulation of soluble salts in the root zone. This may require tile drains.

TOPOGRAPHY

The topography of an area is important in planning for land development, design of water conveyance systems, application and control of water, and control of erosion.

Slope refers to the incline or gradient of the surface of the area and is measured in per cent, the difference in elevation in feet per 100 feet of horizontal distance. A 5 per cent slope rises or falls 5 feet per 100 feet of horizontal distance. Slope shape is another important characteristic. A convex slope curves upward like the surface of a ball, a concave slope curves downward like the 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. As an 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. As an example: the knoll and pothole land form on glacial till plains. Slope is important not only because of its effect on soil formation but also because of its influence on runoff, soil drainage, erosion, the use of machinery, choice of crops, and the management practice that may be required. Soil areas with slope gradients greater than 5 per cent are generally considered unsuited for irrigation of crops but in some cases may be suitable for pastures.

Degree and uniformity of slope influences selection of an irrigation method. Permissible slopes vary with soil conditions and with the method of water application. For example: sandy soils usually erode more readily with surface irrigation systems than with sprinkler systems and therefore require gentler slopes of shorter length.

An area can be modified by earth moving equipment, but the economics of the operation must be evaluated against changes in soil condition and anticipated crop yields.

EROSION CONTROL

An important consideration regarding the selection of an irrigation method is erosion control. Nonuniform application of water to the soil may cause erosional losses resulting in an uneven distribution of water. This could concentrate the water in channels, ultimately resulting in gullies and ponding in the lower parts of fields.

After harvest of many crops the soil often is bare and subject to wind erosion. The wind may remove part or all of the surface soil layer or move it about, resulting in an uneven surface. This affects the distribution of water. Moreover, transported soil particles can fill irrigation ditches, thus increasing maintenance costs.

Water distribution systems should convey water with low seepage losses and little soil erosion. However, some soils, because of their texture and structural stability, are not suitable for ditches and special attention is required in their development.

WATER QUALITY

The quality of irrigation water is determined by its salt and suspended material content. The most important salt factors are the total concentration and type of salts. The principal salts include the cations calcium, magnesium, and sodium and the anions carbonate, bicarbonate, sulfate, and chloride. The presence of toxic ions such as borate, usually present in low concentrations, is a factor in some areas of the country, but as yet is not a factor in North Dakota.

The total concentration of soluble salts and the relative proportion of sodium to the other cations are important characteristics determining the quality of irrigation water. The total concentration of soluble salts is expressed in terms of the electrical conductivity (EC x 10^6). The relative proportion of sodium to the other cations is expressed by the sodium-adsorption ratio (SAR).

Figure 3 presents a diagram for the classification of irrigation water.

The interpretation of the classification is as follows: (11)

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. Plants with moderate salt tolerance can be grown in most cases 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 the 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, unless gypsum is present in the soil. This water may be used on coarse textured soils with moderately rapid to very rapid permeability.

S3 - High sodium water - may produce harmful levels of exchangeable sodium in most soils and will require special soil management, good drainage, high leaching, and organic matter additions. Chemical amendments may be required for replacement of exchangeable sodium, except that amendments may not be feasible with waters of very high salinity.

S4 - Very high sodium water - is generally unsatisfactory for irrigation purposes except at low and perhaps medium salinity, where the solution of calcium from the soil or use of gypsum or other amendments may make the use of these waters feasible.

Boron

Boron is essential to the normal growth of all plants, but the quantity required is very small. It can occur in toxic concentrations in irrigation waters, making them unsuitable for use. Boron is very toxic to certain

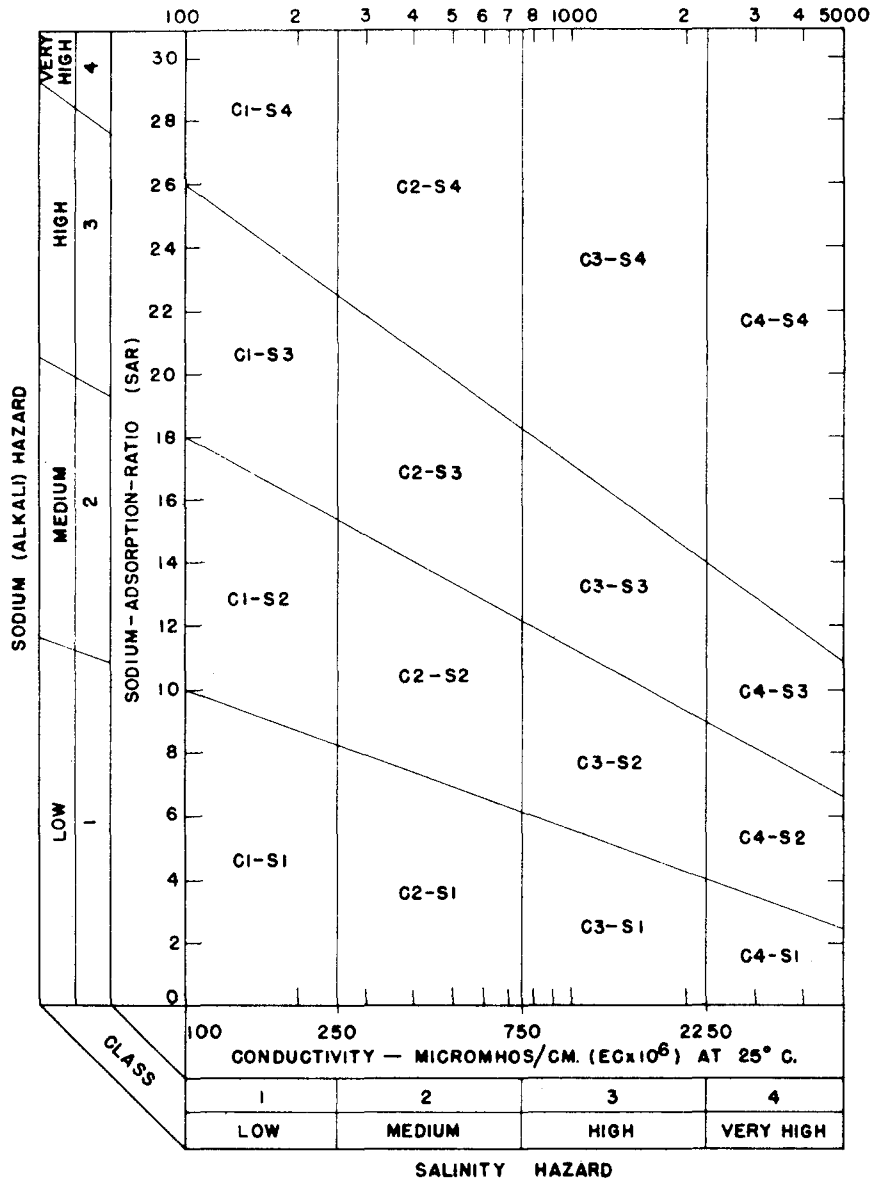


Figure 3. Diagram for the classification of irrigation waters

plant species and the concentration that will injure these sensitive plants is often approximately that required for normal growth of very tolerant plants. The occurrence of boron in toxic concentrations in certain irrigation waters makes it necessary to consider this element in assessing the water quality.

Bicarbonate

High concentrations of bicarbonates and carbonates may have an indirect effect on water quality through the precipitation of calcium and magnesium, thereby increasing the sodium hazard.

In evaluating irrigation water quality, first consideration should be given to the salinity and alkalinity hazards, than to the potentially toxic elements.

The concentration of salt in the soil solution influences plant growth and soil physical conditions. Undesirable salt accumulation may result from the use of irrigation water containing high salt concentrations. The concentration of salts in the soil solution increases as the soil water is taken up by plant roots and by evaporation. Periodic leaching is necessary to maintain the concentration of salt in the soil at a level that will not adversely affect plant growth. Information regarding infiltration rate, permeability, and concentration and type of salts in the soil and concentration and type of salts in irrigation water are needed to plan management practices.

SUMMARY

Due to the capital required for the development of irrigation, the farm operator must consider all the factors that will influence his decision.

This publication has discussed the factors relating to soil, drainage, topography, and quality of irrigation water. The farm operator should have a complete inventory of these factors when considering irrigation.

County agents, Extension Service and Experiment Station specialists, and personnel from the Soil Conservation Service can assist in providing the needed inventory and help in the evaluation of the factors needed to be considered in deciding if irrigation has potential. The Bureau of Reclamation can assist in providing soil and water factors needed in organized irrigation districts.

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