Evaluating SOIL and WATER For Irrigation

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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 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 material which provides support for plants. In some areas of the state this material is underlain at varying depths by sand, gravel or bedrock, which provides little or no sustenance for the plant. Table 1 presents the soil depth classes used when making standard soil surveys.

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

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 holding 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 water to shallow soils.

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 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
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 presents the soil textural classes.

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

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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.

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 Approximate Available Water Holding Capacities for Various Textural Classes (unpublished data)

Texture	Available Water Holding Capacities, inches of water per inch of soil
Coarse sand and gravel	.02 to .05
Sands	.05 to .08
Loamy sands	.08 to .11
Sandy loams	.11 to .14
Fine sandy loams	.14 to .17
Loams and silt loams	.17 to .22
Clay loams and silty clay loams	.14 to .20
Silty clays and clays	.13 to .17

In most instances, a soil that holds less than three inches of available water in the upper four 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

This soil could be irrigated, but it would be considered marginal, due to the low water holding capacity.

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

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. Movement of air, water and plant roots through a soil depend to a large extent on soil structure. Soils formed of aggregates that disintegrate readily in water require special management. Generally, tilling dry soil tends to destroy its structure, whereas tilling 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 which have high intake rates. Sprinkler methods of water application for soils with high intake rates are usually recommended.

Soil Permeability

Soil permeability refers to the rate at which the soil internally 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 is 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 present, applying water to soils formed in glacial till is not recommended because of the lack of permeability data.

Soil Salinity-Alkalinity

"Saline soils" refers to those soils which contain enough 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 affects plant growth. Soils containing excessive amounts of sodium have poor physical condition.

Saline or 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 to below the root zone of the crops grown. 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 often are 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. Replacing sodium with 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 selecting salt-tolerant crops, special irrigation and tillage practices, and using such soil amendments 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.

Topography

The topography of an area is important in planning for land development, design of water conveyence systems, application and control of water, and control of erosion. Degree and uniformity of slopes influence selecting 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. Non-uniform 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.

Harvesting many crops often leaves the soil 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 water distribution. Moreover, transported soil particles can fill irrigation ditches and thus increase 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.

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Water Quality

Quality of irrigation water is determined by its salt and suspended material content. The most important salt factors are 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 yet is not a factor in North Dakota.

Salt concentration 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. Periodic leaching is necessary to maintain the concentraton 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 irrigation water are needed to plan management practices.

Summary

Due to the capital required to develop irrigation, it is necessary for the farm operator to consider all the factors that will influence his decision.

This paper 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 factors.

References

1. Hagan, R. M., H. R. Haise, and T. W. Edminster, editors. 1967. *Irrigation of Agricultural Lands.* Agronomy Monograph 11. Amer. Soc. of Agron. Madison, Wis.
2. Israelson, O. W., and V. E. Hanson. 1965. *Irrigation Principles and Practices.* Wiley and Sons, Inc., New York.
3. Johnsgard, G. A. 1970. *Salt Affected Problem Soils in North Dakota.* North Dakota Extension Bulletin No. 2.
4. Omodt, H. W., G. A. Johnsgard, D. D. Patterson and O. P. Olson. 1968. *The Major Soils of North Dakota.* North Dakota Agr. Exp. Sta. Bull. No. 472.
5. Pair, C. H., editor. 1969. *Sprinkler Irrigation.* Sprinkler Irrigation Association, Washington, D. C.
6. Patterson, D. D., G. A. Johnsgard, M. D. Sweeney and H. W. Omodt. 1968. *Soil Survey Report-County General Soil Maps-North Dakota.* North Dakota Agr. Exp. Sta. Bull. 473.
7. Soil Survey Manual. 1951. United States Department of Agriculture. U. S. Government Printing Office, Washington, D. C.
8. Thorne, D. W., and H. B. Peterson. 1954. *Irrigated Soils.* The Blakiston Co., Inc., New York.
9. U. S. Salinity Laboratory Handbook No. 60. 1954. United States Department of Agriculture. U. S. Government Printing Office, Washington, D. C.