Natural Conditions of Salt Accumulations in North Dakota

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North Dakota has large areas with salt-affected soils and potential conditions for soil salinization. In these areas, the geologic materials, relief, ground waters, natural drainage, and climate are favorable for salt accumulation. Johnsgard (1967) identified over one million acres of land affected by salinity in North Dakota, out of which about 400,000 acres are in the Red River Valley (Benz et al., 1961). This article describes the natural conditions determining salt accumulation in waters and soils of North Dakota.

The accumulation of salts in soils take place under the influence of four natural factors: 1) a salt source, 2) a salt carrier, 3) an accumulation factor, and 4) a salt concentration factor. Man's activity may add a fifth factor, management practices.

Salt Sources

The formation of salt-affected soils is generally well related to the salt content of soil parent materials. The situation in North Dakota is unique from this point of view. Salt levels found today are a result of the salt accumulation from sea water that at one time covered the Williston Basin and desalinization of the land under the influence of glaciation. The Williston Basin covered the western part of the state. The salt-affected soils found there developed from old marine deposits exposed to the soil surface. Glaciation covered the central and eastern part of the state. Salt-affected soils in this area are related in some cases with marine deposits but are mainly associated with shallow saline water table. Most salt-affected soils around saline lakes and portions of the Red River Valley are in this category.

More than half of North Dakota lies within the ancient Williston Basin. During the Cretaceous period and the beginning of the Tertiary period, long before the glacial age, the basin was subjected to periodic invasions from the sea. Sediments of marine origin accumulated periodically, with continental sediment deposits between invasions in and following regression of the sea. Where these marine sediments are exposed at the surface they are soil parent material and source of salts for the soils formed in place (Fig. 1).

The oldest marine Cretaceous deposit is the Niobara formation. It is a shale deposit with white, limy inclusions, and marl deposits. It is exposed on steep slopes in western Pembina and eastern Cavalier counties near the Pembina River and its tributaries.

An important marine Cretaceous deposit is the Pierre formation. It is a noncalcareous offshore sediment that appears on the surface in portions of the southwestern part of the state. In the east it is exposed in the Pembina Hills and along stream channels in the Missouri, Pembina, Sheyenne and James River valleys.

Fox Hill is the last marine deposit from the Cretaceous period. It is largely marine costal sediments of silt and shale, sandstone and siltstone. It is exposed in gentle, rounded slopes along the Missouri River at the extreme southern edge of the state.

The last marine deposit is the Cannonball formation, deposited in the early Tertiary period. It is represented by marine shoreline and offshore sediments deposited during the last transgression of the sea and is formed of sand and mudstone with lenticular and concretionary sandstone. This deposit is exposed on the west bank of the Missouri River as it leaves the state.

Between the Fox Hill and Cannonball formations are two continental non-saline deposits: Hell Creek, the last Cretaceous formation, and Ludlow, the earliest Tertiary formation. Both are river, estury and lake sediments. Originally they were free of salts, but now parts are saline through infiltration from aquifers lying in marine formations above and beneath them.

Where these marine sediments are exposed as soil parent material, geologic saline soils occur. The largest acreage of salt-affected soils is the southwestern part of the state, where soft shales have weathered from Pierre, Fox Hill and Cannonball shales. Saline soils are also found on loess from soft shales.

A large area of salt-affected soils is found in the Red River Valley, mainly around Grand Forks. Special conditions favor salinization of these soils. Lacustrian loam and clay deposits accumulated and have maintained salts from saline ground waters under upward artesian pressure from the Dakota aquifer. Finally, spots of saline soils have formed on alluvial deposits along local stream found all over North Dakota. On these deposits, saline soils occur in two situations: when the alluvium is from marine sediments eroded from the river basin and accumulated as coluvium along river banks, or when ground waters shallower than a critical depth have been concentrated and salinized the soil surface through evapotranspiration.

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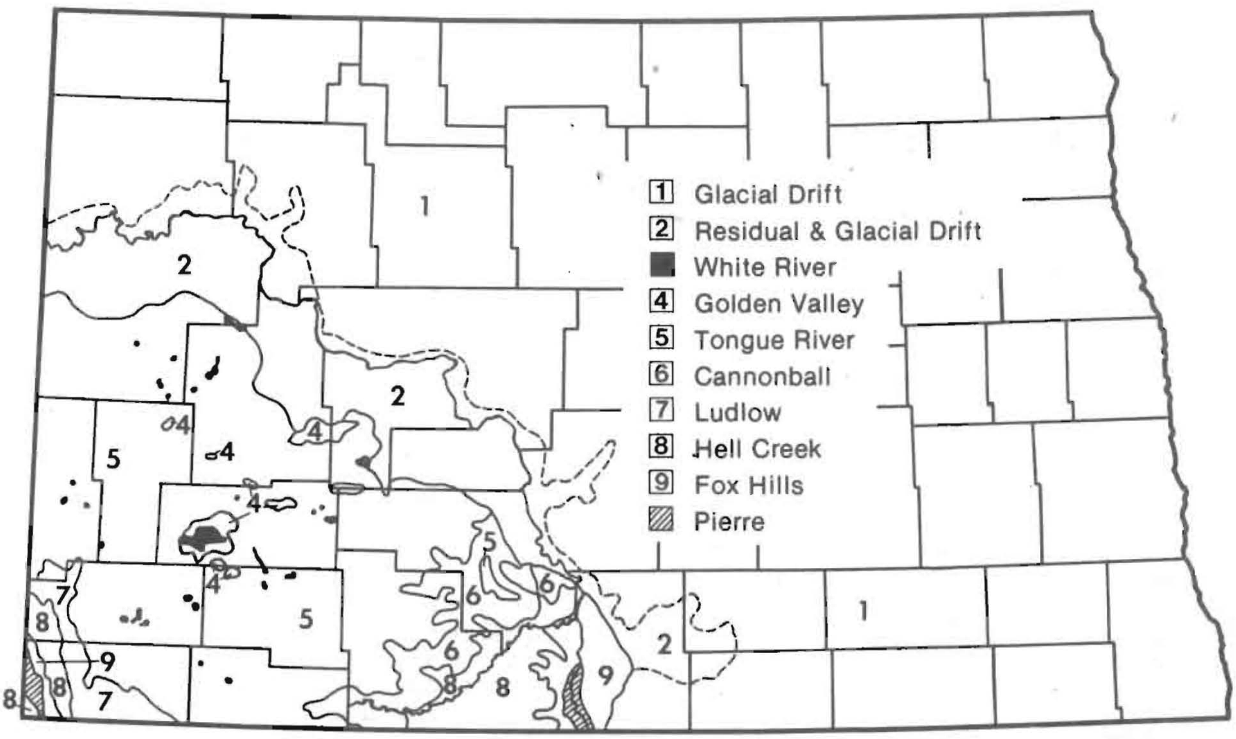

Figure 1. Exposures of sedimentary formations in North Dakota (Adapted from Omodt et. al., 1968).

Water as Salt Carrier

Except where parent materials from salt-bearing rocks form in place, geologic materials cannot be a source of salts in soil if the salts are not first dissolved and carried to a place of accumulation. This is the normal way salt-bearing rocks become a salty parent material. Rivers, lakes and ground waters contain millions of tons of salts leached from geologic deposits from higher elevation and accumulated at lower elevation. Research in the last four years at NDSU shows these salts represent the most important potential for soil salinization in the state.

Using 9,000 available chemical analysis made by Geological Survey of North Dakota in the last 20 years for 83 rivers, eight groups of river waters have been established (Fig. 2). Their chemical composition identifies the quality of salts in the underground deposits and aquifers drained by the state's rivers (Maianu, 1985). The chemical composition of the salts in the different groups of river waters is related to different categories of salt-affected soils.

Lakes present a more homogeneous salt composition, because their waters are immobile and concentrate salts under stable natural conditions. Lakes in two different water groups have been identified (Maianu, 1985).

Deep ground waters have a more complex chemical composition. Over 6,000 ground water samples analyzed in the last 20 years show the state's 32 major aquifers divide into eight groups according to their salt composition (Maianu, Richardson and Held, 1985).

Data on shallow ground waters are inadequate but have a dramatic influence on soil salinization. The Department of Soil Science at NDSU has work underway to collect information to fill this information gap. In this way, the most important indices of soil salinization will be determined for our state: the indices for critical depth and critical salinity of ground water and its effect on salinization. They represent the maximum depth and the minimum salinity of the ground water respectively, which may determine soil salinization. These values are critical for future management of wetlands and cultivated soils with high water tables.

Relief as Salt Accumulation Factor

Information on the sources and carriers of salts are not sufficient for studying the genesis of salt-affected soils. An accumulative factor is also necessary. Depressionary relief, as found in alluvial plains, closed depressions, contacts between a slope and a plane, and flat land around lakes, represents the third formation factor of salt-affected soil, the accumulative factor.

The Red River Valley with its small slope and slow drainage is an example of the most accumulative relief in the state. This is especially true in the Grand Forks area, where not only the surface waters but the ground water under artesian pressure contributed to the accumulation of salts. On a small scale, the same is true with other alluvial or lacustrine valleys; the Souris and Sheyenne valleys are examples.

Large depressions with an imperfect outlet are also salt accumlative relief forms. The Devils Lake depression is an example where the lake itself and surrounding soils bear

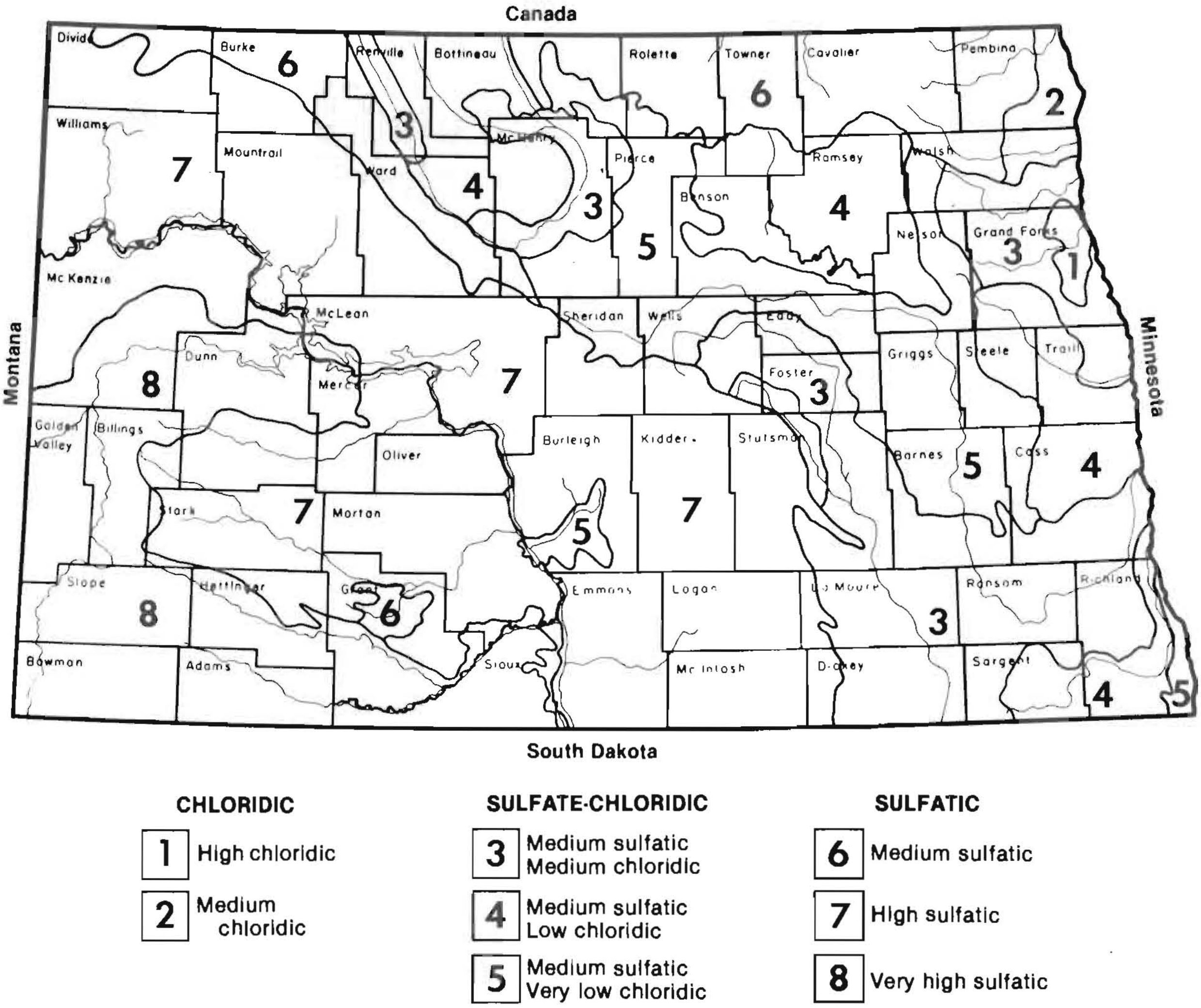

Figure 2. The groups of ND rivers according to their water chemical composition.

large quantities of salts. Smaller salty lakes and surrounding saline soils are scattered across North Dakota.

Finally, the lowest part of some slopes, with salty underground sediments and salty ground waters, present special conditions for soil salinization. As a result of management, mainly too frequent summer-fallowing, saline seeps occur at the foot of these slopes. This is only one of a number of special cases where natural conditions controlling salinization change through management practices.

Climate as Salt Concentration Factor

The source, carrier and accumulation factors are still not enough to explain genesis of salt-affected soils. Soils are saline only when salts concentrate over the limit tolerated by crops. Salts concentrate in the crop root zone when evapotranspiration surpasses precipitation. The precipitation deficit is the active natural factor that concentrates salt in soils. This factor acts when a saline ground water exists at a depth shallower than critical depth or when the soil is irrigated with saline waters.

North Dakota has a continental climate with cold winters and warm summers. The climate is considered "cool temperate subhumid" in the east and "cool temperate semiarid" in the west. On an annual basis the ratio between potential evapotranspiration and precipitation (PET/P) ranges from about 1.4 in eastern North Dakota to about 2.0 in the western part of the state.

Long-time average monthly rainfall shows that from May to September a precipitation deficit occurs (PET/P) all over the state. The deficit is about 8.5 inches in central North Dakota, decreasing from west to east and from south to north. If this amount is applied as irrigation water or is available from shallow ground water which raises through capillarity to the soil surface, salt concentration occurs. The degree of concentration depends on the initial salinity of the evaporated water and the intensity and length of evapotranspiration.

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possess slight bird repellent characteristics that can be enhanced.

In summary, these laboratory experiments support findings from field studies that certain varieties of sunflower possess bird-repellent properties and provide insight into the mechanisms of this repellency. We believe that varietal resistance is a viable approach for reducing the economic losses to sunflower caused by birds. Cooperative research among plant breeders, plant chemists, and vertebrate pest biologists will be needed to develop and evaluate commercially competitive lines of bird-resistant oilseed sunflower.

References

BESSER, J.F. 1978. Birds and sunflower. In Sunflower Science and Technology. (Carter, J.F., ed.). Amer. Soc. Agron., Crop Sci. Amer., Soil Sci. Soc. Amer. Inc., Madison, WI, pp. 263-278.

DOLBEER, R.A., P.P. WORONECKI, R.A. STEHN, G.J. FOX, J.J. HANZEL, AND G.M. LINZ. 1986. Field trials of sunflower resistant to bird depredations. North Dakota Farm Research 43(6):21-24.

FOX, G.J. AND G.M. LINZ. 1983a. Bird resistant sunflower. Proc. Sunflower Research Workshop, Minot, ND, 10-11.

FOX, G.J. AND G.M. LINZ. 1983b. Evaluation of red-winged blackbird resistant sunflower germ plasm. Proc. Bird Control Seminar, Bowling Green State Univ., Bowling Green, OH, 9:181-189.

FOX, G.J., G.M. LINZ, AND L. LINZ. 1984. Development of bird resistant sunflower lines. Proc. Sunflower Research Workshop, Bismarck, ND, 8.

MASON, J.R. AND R.F. REIDINGER. 1983. Importance of color for methiocarb-induced food aversions in red-winged blackbirds (*Agelaius phoeniceus*). J. Wildl. Manage. 47:383-393.

PARFITT, D.E. 1984. Relationship of morphological plant characteristics of sunflower to bird feeding. Can. J. Plant Sci. 64:37-42.

PIFFERI, P.G. AND A. VACARRI. 1983. The anthocyanins of sunflower: II. A study of the extraction process. J. Food Technol. 18:629-638.

ROGERS, J.G. 1974. Responses of caged red-winged blackbirds to two types of repellents. J. Wildl. Manage. 38:418-423.

VACARRI, A., P.G. PIFFERI, AND G. ZACCERINI. 1982. Anthocyanins of sunflower (*Helianthus annus*). J. Food Sci. 47:40-42.

WINER, B.J. 1962. Statistical principles in experimental design. McGraw-Hill Book Co., New York, NY. 907 pp.

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These data indicate conditions for soil salinization exist over all the state where the saline ground waters are shallower than critical depth. In addition, conditions for salinization occur anywhere a saline water is used for irrigation, or where saline ground water is raised higher than critical depth through poor irrigation management, or through too frequent summer fallowing which promotes saline seeps.

Natural conditions of salinization in North Dakota help to identify reclamation methods and preventive measures against salinization. Reclamation includes draining high level saline groundwaters and leaching salts already concentrated in the soil root zone. Prevention includes using good quality irrigation waters and maintaining groundwater levels as deep as possible.

References

Benz, L.C., R.H. Mickelson, F.M. Sandoval and C.W. Carlson. 1961. **Ground-Water Investigations in a Saline Area of the Red River Valley, North Dakota.** Journal of Geophysical Research, 66:2435-2443.

Johnsgard, G.A. 1967. **Salt Affected Problem Soils in North Dakota.** Extension Bulletin No. 2, Cooperative Extension Service, North Dakota State University, 15 pp.

Maianu, A. 1985. **Salt Accumulation in the Rivers of North Dakota.** Journal of Environmental Quality, 14:211-217.

Maianu, A. 1985a. **Salt Accumulation in the Lakes of North Dakota.** (In revision).

Maianu, A., J.L. Richardson and P. Held. 1985. **Patterns of Salt Accumulation in the Groundwaters of North Dakota.** (In revision).

Omodt, H.W., G.A. Johnsgard, D.D. Patterson and O.P. Olson. 1968. **The Major Soils of North Dakota.** Bull. No. 472, Department of Soil Science, North Dakota State University, Fargo, 60 pp.