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SOLONETZ (SN)

The Reference Soil Group of the Solonetz accommodates soils with a dense, strongly structured, clayey subsurface horizon that has a high proportion of adsorbed sodium and/or magnesium ions. The name 'Solonetz' (from R. sol, salt, and etz, strongly expressed) has become somewhat confusing now that most saline soils, with or without a high proportion of adsorbed sodium ions, key out as Solonchaks in the WRB key. Internationally, Solonetz are referred to as 'alkali soils' and 'sodic soils', 'Sols sodiques à horizon B et Solonetz slodisés' (France), Natrustalfs, Natrustolls, Natrixeralfs, Natrargids or Nadurargids (USA) and as Solonetz (USSR, Canada, FAO).

Definition of Solonetz

Soils having a natric horizon within 100 cm from the soil surface.

Common soil units:
Vertic, Salic, Gleyic, Mollic, Alcalic, Gypsic, Duric, Calcic, Stagnic, Humic, Albic, Takyric, Yermic, Aridic, Magnesic, Haplic.

Summary description of Solonetz

Connotation: Soils with a high content of exchangeable sodium and/or magnesium ions; from R. sol, salt, and etz, strongly expressed.

Parent material: unconsolidated materials, mostly fine-textured sediments.

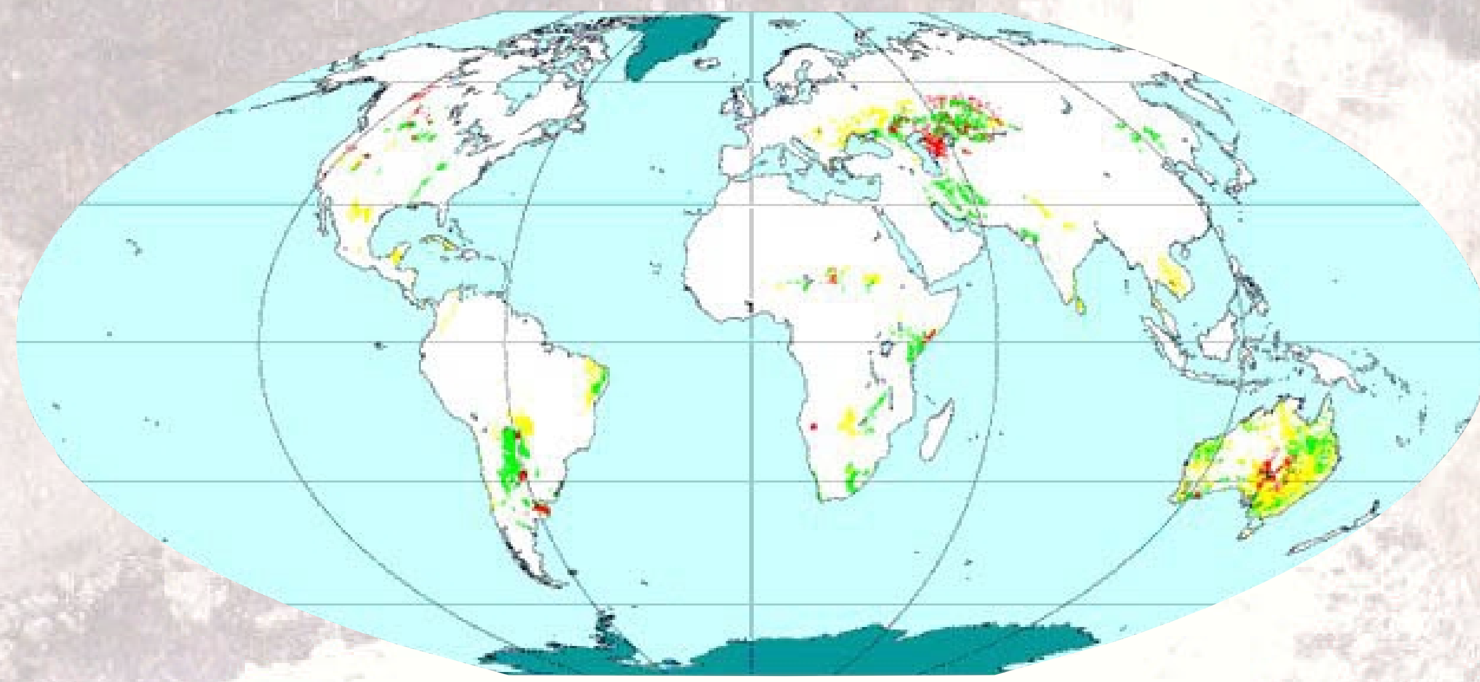
Environment: Solonetz are normally associated with flat lands in a climate with hot, dry summers, or with (former) coastal deposits that contain a high proportion of sodium ions. Major concentrations of Solonetz are in flat or gently sloping grasslands with loess/loam or clay in semi-arid, temperate and sub-tropical regions.

Profile development: ABtnC- and AEBtnC-profiles with a black or brown surface soil over a natric horizon that starts at less than 100 cm from the soil surface. Well-developed Solonetz can have a (beginning) albic eluviation horizon directly over a natric horizon with strong round-topped columnar structure elements. A calcic or gypsic horizon may be present below the natric horizon. Many Solonetz have a field-pH around 8.5 indicative of the presence of free sodium carbonate.

Use: high levels of exchangeable sodium ions affect arable cropping, either directly (Na-toxicity) or indirectly, e.g. because of structure deterioration when soil material with a high proportion of adsorbed sodium and/or magnesium ions is wetted. Many Solonetz in temperate regions have a humus-rich surface soil and can (still) be used for arable farming or grazing; Solonetz in semi-arid regions are mostly used as range land or lie idle.

Regional distribution of Solonetz

Solonetz occur predominantly in areas with a steppe climate (dry summers and an annual precipitation sum of not more than 400 to 500 mm), in particular in flat lands with impeded vertical and lateral drainage. Smaller occurrences are found on inherently saline parent materials (e.g. marine clays or saline alluvial deposits). Worldwide, Solonetz cover some 135 million hectares. Major Solonetz areas are found in the Ukraine, Russia, Kazakhstan, Hungary, Bulgaria, Rumania, China, USA, Canada, South Africa and Australia. In the past, Solonetz were frequently lumped with Solonchaks into one broad soil group: the "salt-affected soils". However, Solonetz need not be saline and Solonetz and Solonchaks often have quite different morphological and physico-chemical properties, and consequently also different management requirements. At present, Solonetz and Solonchaks are separated at a high taxonomic level in most national soil classification systems.



Dominant Associated Inclusions Miscellaneous lands

Figure 1. Solonetz worldwide.

Associations with other Reference Soil Groups

Solonetz are frequently associated with:

- Chernozems and Kastanozems, mainly in landscapes with loess-loam that have some micro-relief and poor surface drainage (e.g. in the Hungarian 'puszta', the flat lands of the Volga delta in Russia, and the central part of the Canadian shield);
- Solonchaks in arid and semi-arid regions, in particular in the central and peripheral parts of large depressions;
- Histosols, notably in bottom lands in eolian (loess-covered), lacustrine and riverine landscapes within the steppe zone;
- Vertisols in plains that are affected by saline groundwater, e.g. in the Gezira region of the Sudan.

Micro-relief, periodical water logging, and the spatial variability of soil and groundwater salinity determine lateral soil sequences in Solonetz regions.

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Genesis of Solonetz

The essential characteristic of Solonetz is their natric subsurface horizon, which shows signs of clay translocation and has an '*Exchangeable Sodium Percentage*' (ESP) of 15 or greater in the upper 40 cm of the horizon. The ESP, defined as '100 * exchangeable Na / CEC', reflects the chemical composition of the soil solution in equilibrium with the solid soil material *under conditions as prevailed during the CEC determination*. The WRB definition of a natric horizon waives the requirement of ESP > 15 in the upper 40 cm of the natric horizon. It suffices that soil at that depth contains "more exchangeable Mg plus Na than Ca plus exchange acidity (at pH 8.2)" if ESP > 15 in some subhorizon within 200 cm of the surface.

The sodium that is responsible for the high ESP-value may originate from NaCl in areas with a marine history. Many Solonetz in inland areas contain sodium sulphates ($Na_2SO_4.xH_2O$) or $Na_2CO_3.xH_2O$ ('soda') as the dominant sodium compound. It is widely thought that soda can form in two ways:

1 by *evaporation of water* that contains an excess of bicarbonate ions over (Ca^{2+} + Mg^{2+})
2 biologically, by *reduction of sodium sulphate*.

Excess bicarbonate is in practice always sodium bicarbonate, which is eventually transformed to Na_2CO_3. The biological formation of soda from sodium sulphate is said to follow the sequence Na_2SO_4 --> Na_2S --> Na_2CO_3 + H_2S, whereby hydrogen sulfide gas leaves the system. This reaction requires (periods of) anaerobic conditions and the presence of organic matter in addition to sodium sulphate.

The formation of a natric horizon is not (yet) properly researched but seems furthered by annual fluctuations in temperature and soil moisture content. The solubility of common sodium and magnesium compounds in soil such as $Na_2SO_4.10H_2O$, $Na_2CO_3.10H_2O$ and $MgSO_4.7H_2O$, increases sharply over the temperature range from 0 to 30 ^oC (see under Solonchaks; Figure 2). Rapid accumulation of these compounds in the surface soil during dry and hot summer seasons is followed by much slower leaching during the wet but cold winter season.

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Hysteresis between rapid accumulation and slow discharge of sodium and magnesium compounds in the (sub)surface soil is certainly to be expected in regions with a continental climate, where summers are dry and warm and winter precipitation is largely snow that melts in early spring (leaching water temperature close to freezing point). The fact that major Solonetz areas are found in the dry interior parts of North America, Eurasia and Australia, seems to confirm this hypothesis.

The presence of 'free' soda in soil is associated with a field-pH > 8.5. Under such conditions, organic matter tends to dissolve and move through the soil body with rain water or melted snow. The remaining mineral soil material is bleached and in the extreme case a clear eluvial horizon may form directly over the dense natric subsurface horizon. Black spots of accumulated organic matter can be seen in many Solonetz, at some depth in the natric horizon. The dense natric (clay) illuviation horizon poses an obstacle to water percolating downward at the beginning of a wet season. Rain water or snow melt contains little sodium, if any. This causes a sudden drop in the ionic strength and sodium concentration of the soil moisture at the wetting front. As a consequence, the water films ('double layers') around individual clay plates become thicker, which weakens the bond between the negatively charged sides of clay plates and the positively charged 'ends' of other plates. Soil aggregation is then weakened and the soil material peptises. This process is held accountable for the rounded tops of (columnar) structure elements in the mature natric horizon. Where the surface soil is subsequently lost because of erosion, the exposed natric horizon shows a characteristic 'cobblestone' pattern. Black flakes of translocated organic matter can often be seen on top of the exposed natric horizon alongside whitish, bleached mineral particles. It has been reported that in extreme cases silica and alumina will even dissolve from silicate clays at the upper boundary of the natric horizon.

Note that not all Solonetz contain soda and have a high field-pH! Solonetz can also form through progressive leaching of salt-affected soil. Even soils that were initially rich in calcium may eventually develop a natric horizon. Prolonged leaching and exchange of adsorbed Na^+ by H^+ will ultimately produce a bleached eluvial horizon with a low pH. Such strongly degraded soils are known as '*Solods*'.

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Characteristics of Solonetz

Morphological characteristics

'Typical' Solonetz feature a thin, loose litter layer resting on black humified material about 2-3 cm thick. The surface horizon is brown, granular and shallow but can also be more than 25 cm thick; it is easily eroded away. If still present, it normally overlies a brown to black, coarse columnar or prismatic, natric subsurface horizon. Structure elements in the natric horizon might be covered by thick, dark cutans of clay and/or translocated organic matter, especially if the soil reaction is strongly alkaline. Where the tops of columnar structure elements have become rounded, they may be covered with bleached, powdery fine sand or silt. In strongly degrading Solonetz, a bleached 'albic horizon' may be present between the surface horizon and the natric horizon. The natric horizon grades with depth into a massive subsoil.

Hydrological characteristics

Clayey Solonetz are nearly always slowly permeable to water. Rapid slaking of surface soil during rain showers (or surface inundation) and subsequent ponding of water on top of dry (sic!) soil is a common problem. Shallow drainage gullies are a common feature even in (nearly) flat depression areas, which demonstrates how rapid peptisation of surface soil is conducive to water erosion of Solonetz.

Physical characteristics

Most Solonetz are very hard in the dry season and sticky when wet. Clayey Solonetz tend to become lumpy at the surface when ploughed, particularly where the shallow surface horizon was lost and the top of the natric horizon became exposed. The dense natric horizon hinders downward percolation of water and root penetration. There are strong indications that a high percentage of exchangeable magnesium affects the soil structure in a similar manner as a high ESP.

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Chemical characteristics

The high sodium saturation of Solonetz is harmful to plants in several ways.

- Too much sodium in the soil is *directly toxic* to Na+-sensitive plants and disturbs uptake of essential plant nutrients.
- Excess sodium affects plant growth *indirectly* because the dense natric horizon obstructs downward percolation of water and the growth of roots.

The impression exists that sensitive crops (e.g. beans) develop true sodium toxicity symptoms already at low ESP-values whereas tolerant crops such as cotton are stunted at much higher ESP, mainly because of sodium-induced adverse physical soil conditions.

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Management and use of Solonetz

The suitability of 'virgin' Solonetz for agricultural uses is almost entirely dictated by the depth and properties of the surface soil. A 'deep' (say >25 cm) humus-rich surface soil is needed for successful arable crop production. Unfortunately, most Solonetz have only a much shallower surface horizon, or have lost the surface horizon altogether.

Solonetz amelioration has two basic elements:

- improvement of the porosity of the (sub)surface soil, and
- lowering of the ESP.

Most reclamation attempts start with incorporation of gypsum or, exceptionally, calcium chloride in the soil. Where lime or gypsum occur at shallow depth in the soil body, deep ploughing (mixing the carbonate or gypsum containing subsoil with the surface soil) may make expensive amendments superfluous. Traditional reclamation strategies start with the planting of a sodium-resistant crop, e.g. Rhodes grass, to gradually improve the permeability of the soil. Once a functioning pore system is in place, sodium ions are carefully leached from the soil with 'good quality' (calcium-rich) water.

An extreme reclamation method, which was developed in Armenia and successfully applied to Calcic Solonetz soils in the Arax valley, uses diluted sulphuric acid (a waste product of the metallurgical industry) to dissolve $CaCO_3$ contained in the soil. This brings calcium ions in the soil solution, which repel sodium ions from the soil's exchange complex. The practice improves soil aggregation and soil permeability. The resulting sodium sulphate (in the soil solution) is subsequently flushed out of the soil.

Solonetz are problem soils when used for arable agriculture. The prospects for crop production on Solonetz are largely dictated by the thickness of the humus-rich surface layer. Deep ploughing can be tried to improve Solonetz areas where lime or gypsum are present at shallow depth in the soil. This strategy and the use of ameliorants such as gypsum were found to be the most effective on Solonetz under irrigation. Ameliorated Solonetz can produce a fair crop food grain or forage. The majority of the world's Solonetz was never reclaimed and is used for extensive grazing or lies idle.

A word of caution

Soil analytical laboratories determine the Exchangeable Sodium Percentage (ESP) of soil material in a number of steps. First, 'adsorbed bases' are determined by bringing an aliquot of the soil material in contact with a strong electrolyte solution such as 1 *M* NH_4-acetate. After 'equilibrium' is established, repelled 'bases' (Na^+ and Mg^{2+}-ions and others) are determined in the acetate solution. Next, the exchange capacity of the soil material is determined by exposing the same aliquot of soil to another electrolyte solution that is buffered to a constant value, e.g. pH 7.0 or pH 8.2. The ESP-value is calculated by multiplying the quantity of repelled Na^+ (first electrolyte solution) by 100 and dividing the result by the quantity of the repelled replacement cation (determined in second electrolyte solution).

The cation exchange properties of many soil materials are in part pH-dependent. This has consequences: the actual ESP-value *under field conditions* is overestimated if the field-pH exceeds the value of the buffered (second) electrolyte solution and is underestimated if the field-pH is lower. It follows that (widely used) generic tables that suggest orders of crop yield depression as a consequence of high ESP-values overestimate damage if the field-pH exceeds the pH of the buffered electrolyte solution and underestimate damage is the field-pH is lower. This explains why cotton can be produced in the Gezira region of Sudan (field-pH > 8.5 and a *measured* ESP-value of 35%) even though tests in the United States indicated a tolerable ESP-level of only 16% (at a field-pH close to 7.0). Generic tables on the damage inflicted by high sodium levels are to be used with great caution!