Mapping of Salt Affected Soils

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Introduction

Salt affected areas are extended on all the continents and cover approximately 10% of the total land surface of our globe. In spite of the fact that they are far from being evenly distributed in the various regions more than 120 different countries are confronted, to a smaller or to a greater degree, with the problems of soil salinity.

In the last decades salt affected soils have been discovered even in those areas where this phenomenon was not known earlier even by specialists, namely in countries of the humid tropics like Ghana, Ethiopia, Puerto Rico, Zimbabwe as well as in regions over the polar circle like Yakutia and Alaska. Even in the Antarctic various kinds of salt affected soils were found and new information appeared in the technical literature on their existence, properties and practical significance.

The problem of salt affected soils exists at present as a global problem and if we include in this group all the soil formations which develop under the decisive influence of electrolytes in the soils they will be found diverse and to evolve in more countries and areas than has been assumed.

Practical grouping and short characterization of salt affected soils

If we agree, for the purpose of wording, a basic definition of salt affected soils that all the soil formations which develop due to the dominant role of different salt solutions in the soil forming processes belong to this group then we cannot limit our attention to saline and alkali soils in spite of the fact that they are the major groups of salt affected soils.

In Table 1 a simple but practical grouping system of salt affected soils is demonstrated including all those soils which are accordingly to be considered as salt affected.

Salt affected soils, in the broader sense, can be divided into the following groups:

1. Saline soils that develop under the influence of electrolytes of sodium salts with nearly neutral reaction /dominantly Na_2SO_4, NaCl, seldom

$NaNO_3$/. These soils occur mainly in arid and semiarid conditions and form a major part of all the salt affected soils of the world.

2. The alkali soils that develop under the influence of electrolytes capable of alkaline hydrolysis /mainly Na_2CO_3 and $NaHCO_3$ and seldom Na_2SiO_3 and $NaHSiO_3$/. This group is well extended practically in all climatic regions of the world from the humid tropics to beyond the polar circles and their total salt content is commonly lower than that of saline soils and sometimes even strongly alkaline.

3. The salt affected soils that mostly develop owing to the presence of $CaSO_4$ /gypsiferous soils/ or, rarely, in the presence of $CaCl_2$. Gypsiferous soils can be found mainly in the arid and semiarid regions of North America, North Africa, the Near-, Middle- and Far-East and also in Australia.

4. Salt affected soils which develop under the influence of magnesium salts. This group occurs in arid, semiarid and even semihumid conditions and has a particular significance especially in soils with heavy texture.

5. Acid sulphate soils in which the salt content is composed mainly of $Al_2(SO_4)_3$ and $Fe_2(SO_4)_3$. This type of salt affected soils is broadly extended in the tidal marsh areas along the seashores of all the continents. They are particularly common in North Europe, the western and eastern coastlines of Africa, along the coastline of Indo-China, etc. and develop on sulphur containing marine sediments.

Evidently the different groups of salt affected soils have diverse physico-chemical and biological properties besides the one they have in common, i.e. comparatively high electrolyte content.

Table 1

Grouping of salt affected soils

Electrolyte/s/ causing salinity and/or alkalinity	Type of salt affected soil	Environment	Main adverse effect on production	Method for reclamation
Sodium chloride and sulphate /in extreme cases nitrate/	Saline soil	Arid and Semiarid	High osmotic pressure of soil solution /toxic effect/	Removal of excess salt /leaching/
Sodium ions capable of alkaline hydrolysis	Alkali soils	Semiarid Semihumid Humid	Alkali pH Effect on water physical soil properties	Lowering or neutralizing the high pH by chemical amendments
Magnesium ions	Magnesium soils	Semiarid Semihumid	Toxic effect High osmotic pressure	Chemical amendments Leaching
Calcium ions /mainly $CaSO_4$/	Gypsiferous soils	Semiarid Arid	Acidic pH Toxic effect	Alkaline amendments
Ferric and aluminium ions /mainly sulphates/	Acid sulphate soils	Sea shores, lagoons with heavy, sulphate containing sediments	Strongly acidic pH, toxic effect	Liming

In Fig. 1 the pH spectrum of different salt affected soils is presented. It clearly shows that nearly the whole pH range is represented by the big family of various types of salt affected soils. There is no other group of soil formations with such diversity of pH values.

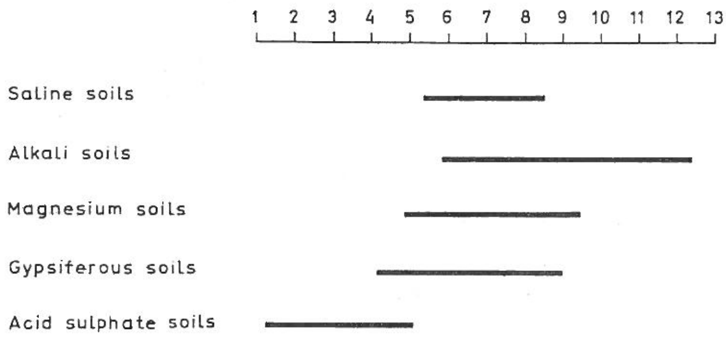

Fig. 1
The pH spectrum of different salt affected soils

Besides the salt affected soils developing due to the natural soil forming processes, so-called secondary salt affected soils have an increasing importance, both scientific and practical. Secondary salt affected soils are those which have been salinized due to man-made factors, mainly as a consequence of improper methods of irrigation. The extension of secondary salt affected soils is rather sizeable and this adverse process is as old as irrigated agriculture itself. Old civilizations in Mesopotamia, China and Pre-Columbian America fell in consequence of the salinization of irrigated land. The process is considerable also at present and more than half of all the existing irrigation systems of the world are under the influence of secondary salinization and/or alkalization.

When speaking of the man-made factors of salinization we also have to mention potential salt affected soils which are not salt affected at present but in case of the extension of irrigation, deforestation, overgrazing and other man-made measures, can and will be salinized in the future unless the necessary preventive procedures are undertaken in due time. No global records are available of the size of potential salt affected soils but their area is larger than that of existing salt affected soils.

The outlined grouping and characteristics have been elaborated by the author of this paper and it is one of the many existing classification systems for salt affected soils. This system has been devised especially for salt affected soils without covering other soil formations.

In most general classification systems and legends of soil maps salt affected soils are included at lower or higher taxonomical levels. This is the reason why salt affected soils appear in these soil maps under different terms, in very different classification units, either separated from other soil types or merged into them.

While such, mainly of low scale soil maps can be acceptable for general purposes /teaching physico-chemical characteristics of landscape, etc./ it is necessary to carry out special soil survey and mapping for salt affected areas whenever the geochemical geo-pedological, or practical /irrigation,

Fig. 2
Global distribution of salt affected soils on the world

land melioration/ aspects are of interest. Particularly for practical purposes special mapping methods, too, are necessary for salt affected areas as well as an appropriate interpretation of such maps.

Evidently the scale of the map depends on the purpose of mapping and the scale of the map determines the taxonomical hierarchy expressed in the classification and legends. In the following, several approaches to the preparation of specific soil maps of salt affected areas will be demonstrated and discussed including large, medium, and small scale maps.

Small scale maps of salt affected soils

Scales < 1:5,000,000

Low scale maps for salt affected areas are applicable for the general characterization of the distribution of salt affected soils globally, on one continent or subcontinent. Evidently it is hardly possible to apply a detailed classification of salt affected soils to such general maps; they are more suitable for reconnaissance studies of a large territory or for representing the general characteristics of the territory concerned.

Fig. 2 is a very small scale map showing the global distribution of salt affected soils on the world. The original of this map was prepared on the scale of 1:15,000,000.

Due to the fact that the different types of salt affected soils often occur jointly or intermixed and sometimes in complex with non-salt affected soils, it is evident that in maps like the one shown above it is hardly possible to separate in the legend the different types of salt affected soils. This is why no such distinction was made. Fig. 2 only demonstrates the spots where, to a larger or smaller extent, salt affected soils occur in different regions of the world. It also shows those areas where salinization affects bigger areas and those areas which are little or not affected by the salinization of soils. It is clearly visible that no continent is free from salt affected soils and although they are more frequent in the arid zones they also largely occur in non-arid climatic conditions. They occur as north as over the polar circle and also in tropical conditions near and over the equator.

Medium scale maps of salt affected soils

Scales 1:100,000 to 1:5,000,000

Medium scale maps are suitable not only for the general characterization of given areas but also for representing some more detailed environmental conditions and even for underlying recommendations for environmental planning and production. This type of map is also good for the estimation of the extent of the different kinds of salt affected soils in a given territory, e.g. in a small country or in a river basin. If the scale is closer to the 1:100,000 than to the other extreme of this range, planning of land utilization, particularly irrigation and drainage, is also possible by the application of the map.

In Fig. 3 the saline and alkali soils in Europe are presented according to the original scale of 1:2,500,000.

It is a typical example of the less detailed maps of this range. As it can be seen in Fig. 3 this scale enables the representation of several types of salt affected soils, namely in the given case, the solonchak and different solonetz soils in Europe. It was even possible to show territories of potential salinity which surpass that of the present salt affected soils.

Fig. 3

Saline and alkali soils in Europe. 1. Solonetz soils. 2. Soda-solonchak soils. 3. Chloride and sulphate solonchak soils. 4. Potentially salt affected soils

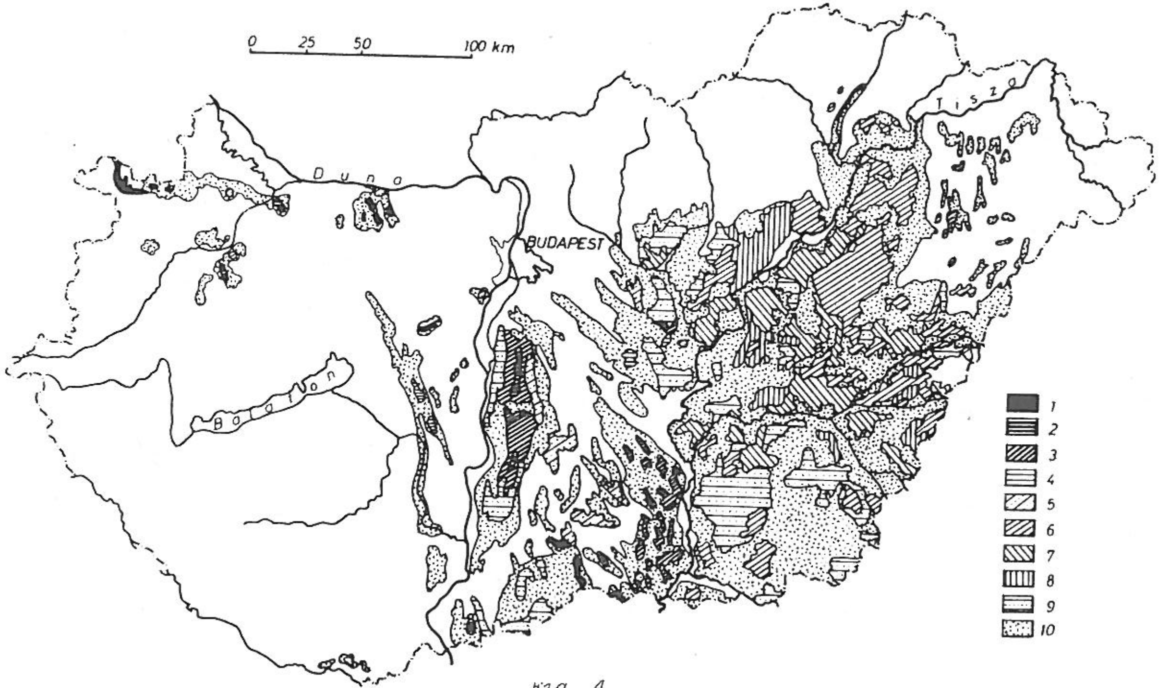

Fig. 4

Distribution of salt affected soils in Hungary

According to the Hungarian soil classification:	According to the classification accepted by the Subcommission on Salt Affected Soils of the ISSS:
1. Chloride and/or sulphate solonchaks	Saline soils
2. Sodic solonchak 3. Sodic solonchak-solonetz	Alkali soils without structural B horizon
4. Calcareous meadow solonetz 5. Calcareous solonetzic meadow soil	Alkali soils with structural B horizon, calcareous
6. Meadow solonetz 7. Meadow solonetz turning into steppe formation 8. Solonetzic meadow soil	Alkali soils with structural B horizon, non-calcareous
9. Chernozem and meadow cherozem salty in deeper layers 10. Potentially salt affected soils	Potentially salt affected soils

Another example of maps made according to a medium scale of the given range is Fig. 4 showing the salt affected soils in Hungary.

The original scale of this map is 1:500,000 which gives the possibility for distinction of as many as 10 different types of salt affected soils /given in the legend of the map/ according to Hungarian soil classification and 5 groups according to the classification of the Subcommission on Salt Affected Soils of the International Society of Soil Science, respectively.

The legend of this map also shows the good correlations between the Hungarian classification system for salt affected soils and that of the Subcommission on Salt Affected Soils of the International Society of Soil Science.

The scale 1:500,000 is acceptable for many possible applications of the map, i.e. teaching, use for deciding environmental issues, planning irrigation, drainage and even agricultural production, including crop patterns and amelioration.

Evidently the scales described above are still not sufficient for construction projects of irrigation, drainage, land consolidation and soil amelioration and are even less usable in the course of accomplishing the day-today tasks of production. Nevertheless this scale may help a lot in many fields of science and technology and it is desirable to cover as much as possible from the salt affected areas of the world on at least such medium scale maps.

Large scale maps of salt affected soils

Scales > 1:100,000

The large scale maps of salt affected soils are usable for different purposes, like:

- representing not only different types but also subtypes and varieties of salt affected soils in detail over a small area /a farm or even a field/;
- for elaborating detailed irrigation and drainage patterns and the calculation of irrigation and leaching requirements;
- for elaborating ameliorative measures and calculating the doses of required amendments.

Large scale soil maps near the upper limit of this range can also be very useful in the course of general planning or making decisions in the field of agricultural production for either irrigated or rainfed areas.

As regards the classification of salt affected soils in such maps, the taxonomical levels and units are not only more detailed but also somewhat different from those in medium scale and small scale maps.

Evidently the classification units in large scale maps must be more closely related to the practical requirements than those in maps of small scale even by compromising between the pedological names and practical terms. Often the latter are more suitable for suggesting recommendations for drainage, reclamation materials etc. than the orthodox names of soil units. However, it is advisable to show on the same map or on another map the detailed pedological conditions of the area as well. Later, an example of this approach will be demonstrated and discussed.

In Fig. 5 a large scale map /original scale 1:75,000/ is demonstrated showing the possibilities of sustainable and environmental protecting irrigation in the eastern part of the Hungarian Plain, based on available soil maps, geological, geomorphological, hydrological /both for surface and subsurface hydrology/ maps as well as available existing crop patterns. The aim of this map, which was prepared on the basis of specific surveys, was to enable decision makers to plan, and distribute the irrigated territories in the area.

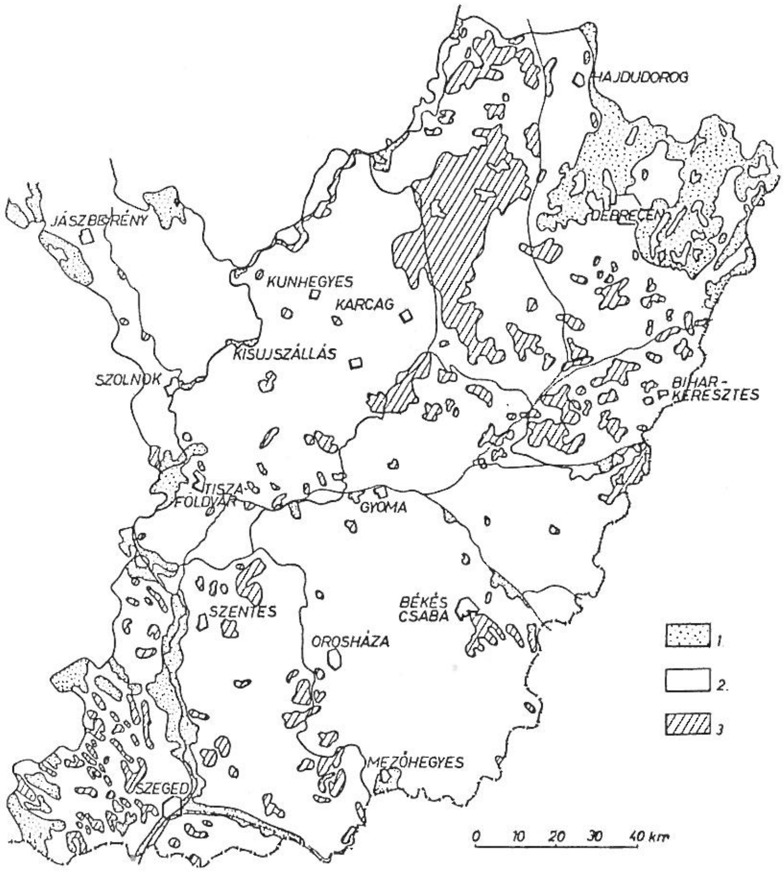

Fig. 5

Possiblities of sustainable and environmental protecting irrigation in the eastern part of the Hungarian Plain. 1. Areas to be irrigated. 2. Areas that may be irrigated conditionally. 3. Areas not to be irrigated

In the late 60s and early 70s of this century big hydroelectric power stations were constructed on the River Tisza and for the Tisza 2 system the above map was also accepted to underlie the construct and distribution of irrigation systems in the territory so that secondary salinization, alkalization and waterlogging could be avoided. As it can be seen, not the detailed soil classification but the target of the survey is demonstrated in the map, and the mapping units were selected accordingly /recommended, not recommended and conditionally recommended for irrigation/.

The above study was followed by a more detailed survey in order to give precise practical recommendations not only for the construction but also for the exploitation of irrigation systems. During this survey, maps were prepared according to the scale of 1:25,000, based on the principle mentioned earlier in this paper, namely to combine soil maps with maps for practical use showing recommendations and numerical values, e.g. for irrigation, control of water depth, etc.

Fig. 6 is a detailed genetic soil map on the scale of 1:25,000 of a given territory in the Hungarian Plain. Here the soil units are identical with the mapping units.

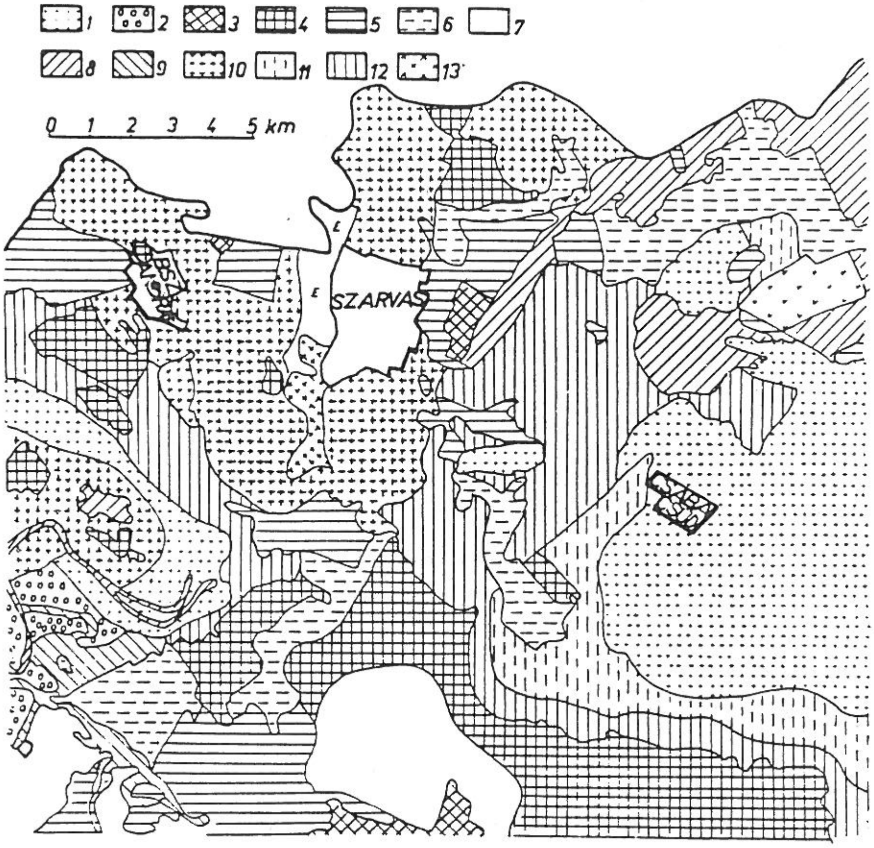

Fig. 6

Detailed genetic soil map for a South-Transtisza region, near Szarvas. 1. Calcareous meadow chernozem soil; 2. Meadow chernozem soil, solonetzic in deeper layers; 3. Shallow meadow solonetz soil; 4. Medium meadow solonetz soil; 5. Deep meadow solonetz soil transitional to steppe formation; 6. Solonetzic meadow soil; 7. Strongly solonetzic meadow soil; 8. Meadow soil; 9. Meadow soil, salty in deeper layers; 10. Alluvial meadow soil; 11. Calcareous chernozem meadow soil; 12. Chernozem meadow soil, salty in deeper layers; 13. Humous alluvial soil

Based on Fig. 6 the following maps were prepared:

1. Map of soil texture and water properties. In this map the soil texture /sand, sandy loam, loam, clay loam, clay and organic soils/, soil categories and soil water properties are indicated.

2. Map of salinity. This map indicates:

- the average total salt content of the soils between the surface and the water table in percentages;
- the max. total salt content of the soil profile in percentages;
- depth of the salt maximum in the soil profile in cm;
- pH value of the B_1 horizon.

3. Map of groundwater conditions which indicates:
- the average depth of the water table in metres;
- the average salt content of the groundwater in g/l;
- the sodium percentage of the groundwater.

4. Map of the "critical depth of the water table". The critical depth of the water table means the depth below which the groundwater cannot provoke salinization.

Fig. 7

Map of possibilities and preconditions of irrigation. A. The possibilities of effective irrigation from the viewpoint of soil conditions: 1. Areas to be irrigated; 2. Areas that may be irrigated conditionally; 3. Areas not to be irrigated. B. The necessary groundwater control: 1. The lowering of the water table; 2. The prevention of a rise in the water table; 3. The regular study of the water table. C. The general directive concerning irrigation: 1. Frequent irrigation is advisable with low water application rates; 2. Medium frequent irrigation is advisable with medium water application rates; 3. One /or infrequent/ irrigation is advisable with a high water application rate

Based on the above maps a map of the possibilities and preconditions of irrigation on the scale of 1:25,000 was prepared /Fig. 7/.

As it can be seen from Fig. 7 the basic principle in legend and recommendations are similar to those in Fig. 5, but they are more detailed supplying the user of the map with valuable guidelines.

These maps represent only one way of mapping salt affected soils on large scales for practical purposes. Such maps may be very diverse in scale, classification system, in selecting the mapping units, according to their target.

Such maps are valuable as tools not only for the better understanding of salt affected soils and their properties but also for the prediction of salinity processes due to irrigation and other human action as well as for elaborating methods for the prevention of adverse processes.