Soil Salinization and its Environmental Hazard on Sustainable Agriculture in East Asia and Neighboring Regions

Satoshi MATSUMOTO[1], Qiguo ZHAO[2], Jingsong YANG[2], Shouquan ZHU[2] and Liqur LI[2]

[1] *Graduate School of Agriculture and Life Sciences, University of Tokyo, Tokyo 113-8657, Japan*
[2] *Institute of Soil Science, Academia Sinica, Nanjing, China*

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1. INTRODUCTION

As a worldwide problem, salinization is an important issue in exploiting and utilizing land resources for sustainable agriculture. Salinization not only affects agricultural production, but also hazards the ecological environment. Asia is the largest continent in the world and also has the largest distribution area of salt-affected soils, amounting to more than one third of the world's total. Along with development of irrigated agriculture, salinization and area of salt-affected soils are expanding. Very few countries in Asia could escape from the hazard of salinization (Szabolcs, 1989). East Asia and its neighboring regions are important agricultural bases of Asia, hence, salinization there is very representative. This paper will discuss salinization in East Asia and its neighboring regions (including China, Japan, Kampuchea, D. P. R. of Korea, Republic of Korea, Laos, Mongolia, Myanmar, Thailand and Vietnam), hazard of salinization on sustainable agriculture and ecological environment, and its management.

2. STATUS OF SALINIZATION IN EAST ASIA AND ITS NEIGHBORING REGIONS.

In East Asia and its neighboring regions, salt-affected land resources are distributed extensively with a huge variety of types, and have tremendous potentialities for exploitation, too, as reserved land resources for people in that part of the world. The total area of salt-affected soils there is about 45.3 million ha, which occupies nearly one third of the total in Asia exclusive of the Asian part of the former USSR.

Definition of salt-affected soils

The concept of salt-affected soils is a general term encompassing two big soil groups, solonchaks and solonetz, and a series of soils salinized or alkalized to various extent. The basic criteria salt or alkali contents are: for solonchak sereis, soils with a soluble salt content in the surface soil layer (generally 0-20 cm) higher than 10 g/kg are defined as solonchaks, and between 10 g/kg and 1 g/kg, classified as salinized soils; and for solonetz series, soils with a pH value over 8.5, exchangeable sodium percentage (ESP) higher than 15% soluble salts less than 5 g/kg or columnar or prismatic structure are defined as solonetz and soils with ESP between 15% and 5% are classified as alkalized soils, However, in nature exist soil types that possess feature of both groups. For instance, in Northeast China, the type of soda-alkalic solonchaks is a typical one of them. In arid regions, some soils have soluble salts accumulated in the subsoil layer during the process of soil formation. This type of soils, considered from the angle of salt-affected soils, are supposed to be sorted as bottom-strata salinized soils or potential salt-affected soils (Wang *et al,* 1993). Potential salt-affected soils are also considered as soils which are neither saline nor alkaline at present, but may result in severe salinization and/or alkalization under human intervention, especially irrigation (Szabolcs, 1989).

Along the coasts of some tranquil bays in the tropics and subtropics, acid sulphate coastal salt-affected soils develop under the effect of the mangrove bio-community which enriches sulfides. When roots and other organic matter in the soils decompose and the soils are drained dry, the sulfides in the soils are oxidized, forming into yellow mottles. The soils, with pH around 4.5 and below, can be divided into acid sulphate soils, acid sulphate solonchaks and potential acid sulphate solonchaks, during its siltation into land or at different poldering and reclamation stages.

Characteristics of soil salinization

The characteristics of the distribution and salinization of salt-affected soils in this part of the world can be summarized as follows:

a) *Horizontal distribution*

Apart from the coastal regions and arid regions where salt-affected soils are distributed in large continuous tracts, salt-affected soils are all scattered in patches over in farm lands or inlaid in other types of soils.

b) *Strong salt-surface accumulation*

It stands for the concentration of the salt-accumulation in the surface soil layer, and less salt enrichment in the subsoils. In the plain regions of East China, the salt surface accumulation is very strong (Table 1).

Salts are mainly concentrated on the land surface in

Table 1 Weighted averages of salt contents in some soil profiles

Soil layer (cm)	0-1	0-5	0-10	0-20	0-40	0-100
Salt content (g/kg)	30-60	12-15	5-8	2.5-4	2-3	0.6-1.5

the form of patches of white salt efflorescence. This kind of salt surface accumulation occurs in the surface soil layer that affects most the root systems of plants (or crops) at the seedling stage, making the plants vulnerable to salt-toxicity or even dying, and thus greatly reducing the crop yield. So this is a noteworthy problem in ameliorating and utilizing the soils. In Northwest China, the feature of salt-surface accumulation remains the same but the thickness of the salic horizon and the amount of salts accumulated increase greatly.

c) *Seasonal dynamics of salt accumulation*

Soluble salts in soils are susceptible to changes of external water (including rainfalls, irrigation). In monsoon regions, salts in soils change seasonally, moving upwards to accumulate in the surface layer in the dry season and leaching downwards in the rainy season. So in a year, there are two time periods, one featuring salt accumulation and the other desalinization. The patterns of salt movement up and down, right and left, are the fundamentals that must be fully understood in managing and ameliorating salt-affected soils. If conditions for desalinization are created, salt content in soils would decrease with a tendency towards desalinization. Otherwise, the salts would keep moving up and down. In that case, the soils may develop toward soil alkalization.

The above description is the characteristics common to all types of salt-affected soils and slightly different only in extent rather than in essence.

Distribution patters of salt-affected soils in East Asia and its neighboring regions

The distribution patterns of salt-affected soils are closely associated with the arid, semi-arid and semi-humid climates, topography and landform, and hydrogeology. Except those of the coastal salt-affected soils, the distribution area and salt accumulation intensity are in general positively correlated with E/P ratio (the ratio of annual evaporation against annual precipitation). The higher the ratio, the larger the distribution area, the more the soil salt and the thicker the salic horizon. In this part of the world, along the tens of thousands of kilometers of coastal lines, coastal salt-affected soils are extensively distributed. In Japan salt-affected soils actually do not exist due to the sufficient precipitation, but some reclaimed lands from the sea or brackish water are scattered along the coastal area. These lands are well managed under the normal weather condition, however they easily suffer from the salinity hazard at the irregular one such as big typhoon. In Korean Peninsular, there are more salt-affected soils along the west coast than on the south and east coasts (Inst. Agr. Sci. & Rural Dev. Ad. Korea, 1985); the Chinese mainland has a total of 18,000 km of coastal lines with enormous shoaly land resources and an extensive distribution of coastal salt-affected soils. Along the coasts to the north of the river mouth of the Minjiang River, particularly to the north of the Changjiang River and the west coast of the Taiwan Island, extensive continuous tracts of coastal salt-affected soils are distributed along the muddy coasts; coastal salt-affected soils feature parallel distribution with the coast and the earlier the formation, the less the soil salts and the closer to the coast, the higher the salt content. The compositions of the salts in soils and in groundwater are quite coincident, both with sodium chloride in dominance. Along the coasts to the south of the Minjiang River mouth, of the Hainan island and further of Vietnam, Kampuchea, Thailand and west Myanmar (Dent, 1990), coastal acid sulfatic solonchaks are distributed disjointedly. The genesis and development of this type of soils are closely related to bio-enrichment of sulfides by mangrove communuties.

In terms of inland salt-affected soils, China ranks the first in area and type, and then come Mongolia, Myanmar and Thailand (Table 2). While in terms of alkalized soils, China also comes the first in area and then Myanmar, who has some in the central part.

In China, alkalized soils are distributed in the pattern of meadow alkalized soils, then steppe alkalized soils and takyric alkalized soils dominating consequently from east to west. In the Huang-Huai-Hai Plain of North China, tile-like crust solonetz with alkalized surface is the typical type and in the Hexi corridor of Gansu, magnesium alkalized soils are

Table 2 Areas of salt-affected soils in different countries

Country	Area of salt-affected soils (unit: M ha)	Source of data
China	99.1*	Wang et al., 1990
	36.9**	Wang et al., 1990
Japan	—	RAPA of FAO (Dent 1990)
Kampuchea	about 0.71	RAPA of FAO (Dent 1990)
D. P. R. of Korea	about 0.04	RAPA of FAO (Dent 1990)
Republic of Korea	0.06	ASI & RDA, 1985
Laos	about 0.12	RAPA of FAO (Dent 1990)
Mongolia	4.07	Szabolcs, 1989
Myanmar	0.63	Szabolcs, 1989
Thailand	1.46	Szabolcs, 1989
Vietnam	0.98	Szabolcs, 1989

* Take all potential salt-affected soils in account
** No take potential salt-affected soils in account

distributed. All these alkalized soils are actually distributed as a soil complexes with solonchaks or alkalic solonchaks. In the Songliao Plain of China, there are large areas of soda alkalic solonchaks, of which the formation is related to the soda-containing pressure-bearing groundwater in the depth. Of inland salt-affected soils, fluvo-aquic solonchaks and salinized fluvo-aquic soils evolved from fluvo-aquic soils being salinized, are widely distributed in China, in every alluvial plain. For example, the Northeast China Plain, the North China Plain, the Inner Mongolian Hetao Plain, the Yinchuan Plain, and some valley plains in Xinjiang, Qinghai and Gansu. The salt composition of the soils is dominantly SO_4-Cl or Cl-SO_4 compounds and the salic horizon is very thin, scattering in patches in the farm lands. In the Junggar Basin, the Tarim basin and the Qaidam Basin of the most inland Xinjiang and Qinghai with arid climate, scarce precipitation, E/P ratio higher than 10 and a long history of salt accumulation, exist extensive continuous tracts of salt-affected soils, of which the types are arid solonchak (including the formerly termed residual solonchak, gypsic-salts pan solonchak), Haplic solonchak and marsh solonchak. In the basins, solonchaks are usually distributed in ring-like patterns. At the end of the course, and inland river, either pools into a lake or disperses and dries up, forming a salt lake or salt shoaly land with an enrichment of halite, carnallite, boron, lithium, gypsum, mirabilite, etc., In the broad arid and semiarid regions of China, distributed are large tracts of various substrate salinized soils, which belong to the category of potential salt-affected soils.

Patters and typical profile properties of salt-affected soils in East Asia and its neighboring regions (EA & NR)

The Map of Salt-Affected Soils in East Asia and its neighboring regions shows the distribution of the soils in this part of the world (provided separately) with mapping units based on the soil maps (including salt-affected soils map) available from those countries and regional and world maps available, as well as some supplementary investigations and surveys. The original mapping units suitable to those areas are adopted as much as possible and at the same time, clarity and artistry are taken into account. So the mapping units should not be too complicated, but capable of reflecting the patterns and regional characteristics of the distribution of salt-affected soils. After investigation and analysis of available data, the following mapping units are worked out. There are:

a. *Gleyic solonchaks*; b. *Salic thionic fluvisols*; c. *Haplic solonchaks*; d. *Gypsic solonchaks*; e. *Salic fluvisols*; f. *Sodic solonchaks*; g. *Potential salt-affected soils*; h. *Solonetz* (including *Haplic solonetz, Fluvo-aquic solonetz, Takyric solonetz,* etc.).

On the connotations and properties of the mapping units, a brief description will be provided with its salt composition as follows.

Gleyic solonchaks. The soils, mainly distributed over river deltas and coastal plains north to 25°N Lat. has developed on river and marine sediment macerated by sea water, with two soil-forming features: a) it is distributed in parallel with the coast, so the earlier the land is formed, the longer it has escaped from tide, the less it contains soil salts, and the closer it is to the coast, the more soil salts it has, b) salt compositions in the soil and in the ground water are quite coinci-

Table 3 Comparison of the mapping units of the map (EA & NR) with these in other classification systems

Mapping units of the map (EA & NR)	Chinese Taxonomic calssification (Inst. Soil Sci., 1991)	FAO-UNESCO World Soil Map. (FAC *et al.*, 1980)
Haplic solonchaks	Haplic solonchaks	Haplic solochaks
Fluvo-aquic solonchaks	Umbrihumic Fluvo-aquic solonchaks	Haplic solonchaks & Salic fluvisols
Alkalic solonchaks	Alkalic solonchaks	Sodic solonchaks
Haplic coastal solonchaks	Coastic solonchaks	Haplicsolonchaks & Gleyic solonchaks
Acid sulfatic coastal solonchaks	Acid-sulfatic solonchaks	Salic thionic fluvisols
Arid solonchaks	Haplic aric solonchaks & Gypsic-salipanic arid solonchaks, etc.	Haplic solonchaks & Gypsic solonchaks
Potential salt-affected soils		
Solonetz	Haplic solonetz: Fluvo-aquic solonetz; Takyric solonetz	Haplic solonetz; Calcic solonetz; etc.

Table 4 Chemical composition of a *haplic solonchak**

Depth (cm)	pH	TSE** g/kg	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^++Na^+
			cmol/1000 g soil						
0-20	8.3	16.89	0	1.05	24.54	2.45	0.43	1.73	25.89
20-40	8.4	10.37	0	1.21	13.91	1.96	0.29	1.26	15.42
40-60	8.1	18.06	0	0.84	27.61	1.81	0.72	0.95	28.60
60-80	8.0	19.27	0	0.68	29.42	2.71	0.43	2.74	29.37
80-100	8.1	16.85	0	0.63	26.08	1.54	0.43	1.00	26.91

* In 1:5 soil-water ratio extraction; soil sampled in Liaoning, China.

** Total salts estimated.

dent, both with sodium chloride in dominance, chloride make 80-95% of the anions and sodium 70-90% of the cations (Table 4).

This type of salt-affected soils occur often in places of flat topography, in the lower reaches of rivers, with insufficient water sources, which is the main obstacle in amelioration the soils with high soil salt content. Growing rice can be the stone killing two birds-amelioration and utilization. China has accumulated much successful experience in this aspect. It is imperative to establish a draining and irrigating system capable of both functions. Growing weeds, crop cultivation and salt - making through evaporation are other approaches to utilization of the land.

Salic thionic fulvisols. The soils are mainly distributed along the coast of tranquil bays and some river deltas south of 25°N Lat. with mangrove bio-community. This type of soils can be found along the coasts in Fujian, Guangdong, Guangxi and Hainan of China, Vietnam, Thailand and Myanmar.

Human economic activities, such as poldering, reclamation, accelerate land formation of the soil, which then can be sorted into 3 soil types according to its developmental stage. Acid sulphate soils, Acid sulfatic solonchaks and potential acid sulphate soils. Acid sulphate soils have a long pondering and reclamation history, some have a 40-50 year history of planting sugar cane and rice. The pH value of the whole profile is less than 4. In the soil layer of 20-50 cm, a layer of mangrove residue can still be found, and light yellow spots and patches are visible on the surface of the solum. In this layer SO_4^{2-} is about 3 times as high as Cl^-.

Acid sulfatic solonchaks are out of reach of sea tide, and remains unreclaimed with mangrove community growing on. In the 0-10 cm surface soil layer, the total salt content is higher than 1%, Cl^- and SO_4^{2-} contents are quite similar, a layer of mangrove residue can be found at 15-35 cm in depth, and the pH value above 35 cm in depth is around 5 (Table 5).

Potential acid sulphate soils spread sea beach, shoaly land and marsh land under sea tide with mangrove community growing on. In the 0-30 cm soil layer, the total salt content is higher than 2%, with Cl^- higher than SO_4^{2-} and the pH value ranges from 4 to 6.

Salinized fluvo-aquic soils and fluvo-aquic solonchaks. Fluvo-aquic soils are derived from fluviatile and lacustrine deposits, and from long-cultivated meadow soils, marshy soils and solonchaks. Strongly subject to the influence of rise and fall of the groundwater, the soils have undergone in its formation moistening process and some salinization process. And those which have experienced both moistening and salinization are sorted into the category of salinized fluvo-aquic soils or of fluvo-aquic solonchaks.

Salinized fluvo-aquic soils and fluvo-aquic solonchaks are distributed mainly in the North China Plain, the Northeast China Plain and valley alluvial plains in Northwest China, where the topography is low and flat with shallow ground water table, mostly less than 3 m. The evaporation-preciption ratio of fluvo-aquic soils in semi-humid and semi-arid regions are beyond 3 and in the arid region of Northwest China over 10. Under such climatic conditions, the upward water flux in soil is much greater than the downward one. Capillarity brings up water to the surface and salts in the groundwater too. Thus the salts accumulate in the surface layer, salinizing the soil. So in the semi-humid, semi-arid and arid regions of China, most of the fluvo-aquic soils show to a different extent the feature of salinization, scattered patches of salt accumulation. The salts consist of sulphate-chloride and chloride-sulphate too (Table 6).

Haplic solonchaks. Haplic solonchaks are distributed in the depressed mid and lower parts of diluvial-alluvial fans and alluvial plains with groundwater table generally round 2.5 m deep and groundwater mineralization 2-20 g/L.

The halophytic and xerophytic vegetation there consists mainly of *S. Collina Pall, Halostachys caspica C. A. Mey., Kalidinm foliatum Moq., Alhagi sparsifolia shap, Apocynum venetum L., Karelinia caspica less., T. Hohenackeri Bge.*.

Salt crust and surface accumulation of salts are visible. In the profile salic horizon develop obviously. Salt content decreases with the depth deepening (Table 7). Salt crystals and grains can be found in the

Table 5 Chemical composition of a *Salic thionic fluvisols** (Moncharoen, 1987)

Depth (cm)	pH 1:1	TSE %	CO_3^{2-}	HCO_3^-	Cl^- Meq/Liter	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^++Na^+
0-10	5.1	4.2	0	0.9	5.9	—	24.1	112.9	463.9
10-35	4.7	1.2	0	0.2	290.8	—	28.8	119.0	335.5
35-72	2.1	4.1	0		206.8	300.5	24.8	173.4	469.5
72-120	2.2	3.8	0		3.1	4.0	24.3	189.2	515.3

* In saturated paste extraction; soil sampled in Chantaburi Thailand.

Table 6 Chemical composition of a *Salic fluvisols**

Depth (cm)	pH	TSE g/kg	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-} cmol/1000 g soli	Ca^{2+}	Mg^{2+}	K^++Na^+
0-5	8.7	12.0	0	1.22	15.02	3.38	0.20	0.77	17.92
5-20	8.7	1.8	0	1.33	0.29	0.94	0.24	0.49	1.60
20-50		3.5	0	2.39	1.16	1.40	0.16	0.69	3.80
50-100		1.7	0	1.06	0.39	0.99	0.20	0.69	1.33

* In 1:5 soil-water ratio extraction; soil sampled in Inner Mongolia, China.

Table 7 Chemical composition of a *haplic solonchak**

Depth (cm)	pH	TSE g/kg	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-} cmol/1000 g soli	Ca^{2+}	Mg^{2+}	K^++Na^+
0-32	8.4	171.1	0.04	0.22	224.0	52.96	28.96	34.30	214.0
32-55	8.7	27.2	0.08	0.20	28.20	17.36	3.64	15.08	27.12
55-90	8.4	52.8	0.04	0.18	46.69	38.16	17.16	17.16	50.75
90-100	8.7	25.3	0.12	0.20	26.83	13.20	6.76	10.92	22.67

* In 1: 5 soil-water ratio extraction; soil sampled in Gansu, China.

Table 8 Chemical composition of *Gypsic solonchaks**

Depth (cm)	pH	TSE g/kg	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-} cmol/1000 g soli	Ca^{2+}	Mg^{2+}	K^++Na^+
0-1		148.5	0.51	2.40	114.9	113.3	25.06	6.27	199.8
1-13		207.5	1.07	4.21	88.63	204.8	57.36	29.40	212.0
13-34		286.9	1.68	2.44	83.49	345.1	35.67	80.35	316.7
34-50		83.0	0.56	1.36	18.15	101.2	19.28	48.2	97.20
50-70		23.5	0.10	0.18	11.86	23.86	14.46	0.96	20.57
70-89		3.9	0.79	0.40	4.36	0.84	0	0	6.38
89-100		3.0	0.79	0.76	1.94	1.16	0.14	0.02	4.39
100-120		3.9	0.47	0.76	2.90	1.83	0	0	5.96

* In 1: 5 soil-water ratio extraction; soil sampled in Xinjiang, China.

salic horizon, and the solum is moist. This type of solonchaks cannot be put in use until excess salts have been leached out of the soil to the extent that is tolerable to corps. Pioneer crops such as rice can be planted first. Amelioration measures of opening drainage ditches and flooding the field to leach salts out should go on. Successful experience has been obtained in Northwest China.

Gypsic solonchaks. The arid solonchaks discussed here include haplic residual solonchaks and gypsic-salipanic residual solonchaks. This type of soils have undergone intensive salt accumulation process as was affected by groundwater and surface water, resulting in a thick salic horizon. However, changes in the natural environment, such as rises of stratum caused by neotectonics, down-cutting or rerouting of rivers, led to a sharp downfall of the groundwater table, thus destroying the conditions for modern salt-accumulation. As the climate there has been very dry with very little precipitation, the salts accumulated in the past have never been leached out of the solum, which thus still contains a large quantity of salts (Table 8). Also some soils with salts accumulated during the geological process have long been out of the influence of the groundwater and begun to develop into desert soil. Yet the gypsum or salt pan formed in the past remains in the soil. The above-described 2 types of soils are both sorted into arid solonchaks.

Arid solonchaks are mainly distributed in the upper part of ancient diluvial-alluvial plains, dried-up deltas and ancient river terraces in semi-arid and arid regions. As the ground water table is as deep as 10m or more, it does not have any effect on the surface soil. The vegetation there are arid flora with a very low coverage of less than 10%. Most of the areas are covered with bare gravels. In Xinjiang, Qinghai, Gansu, Inner Mongolia and Ningxia of China and at the northern foot of the Altai Mountains, distribution of this type of soils could be found.

Sodic solonchaks. Alkalic solonchaks could be found in China and Mongolia. In China, the soils scatter in North China, Northeast China, Northwest China and the Qingzang Plateau. Particularly in Northeast China, the distribution of the soils is large in area and also quite concentrated.

Alkalic solonchaks are mostly distributed in depressed valley plains, inter-sand dune depressions and fan edges and often mixed with soda salinized meadow soil, alkalized meadow soil and meadow solonetz.

On alkalic solonchaks basically no plants or just a few alkali-tolerant plants grow sparsely. The ground water is very high in water table, around 1.5-2.5 m, and also high in mineralization 1-3 g/L, belonging to weakly mineralized sodium-bicarbonate type.

The formation of alkalic solonchaks are the results of long-term subjection to HCO_3-Na type of groundwater. High ground water table makes capillary rise

Table 9 Chemical composition of a *Sodic solonchaks*

Depth (cm)	pH	TSE g/kg	CO_3^{2-}	HCO_3^-	Cl^- cmol/1000 g soli	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^++Na^+	ESP %
0-2	10.6	20.90	21.92	3.19	8.03	2.69	0.02	0.07	35.75	78.88
2-17	10.3	6.13	1.65	2.26	5.27	0.10	0.11	0.10	10.00	54.63
17-31	10.4	4.72	1.36	3.20	1.75	0.05	0.18	0.35	6.75	62.25
31-57	10.2	4.93	1.24	1.79	1.04	3.42	0.33	0.76	5.50	63.13
57-80	10.3	2.96	1.18	1.93	0.66	0.29	0.11	0.15	4.38	56.82
80-100	9.9	1.58	0.86	0.72	0.57	0.07	0.08	0.23	2.57	44.08

* In 1: 5 soil-water ratio extraction; soil sampled in Liaoning, China.

the dominant factor for long, thus causing large accumulation of soda salts. So the soil possesses features of both salinization and alkalization. Table 9 shows its typical profile.

Haplic solonetz

Haplic solonetz are generally inter-located with alkalic solonchaks and alkalized meadow soils, and can be found scattering in Northeast China and Northwest China, generally in raised part and edges of low flat depressions.

The natural vegetation is sparse, consisting of alkali-tolerant meadow and steppe plants. The soil profile possesses an eluvial horizon and columnar alkalic horizon but no district salic horizon. The soil salt content is less than 0.5%, mostly concentrated in the surface layer and subsoil layer. The salt content in the bottom layer is less than 0.1%. The profile structure is: eluvial horizon, 3-10 cm thick, grey in color, plate or scale in structure; alkalic horizon 10-15 cm thick, located just below the eluvial horizon, dark grey in color, compact, columnar or prismatic in structure with gel coating, while spots visible in crevice; parent material horizon, rust streaks, rust spots and new formation of Fe-Mn concretions. The salt composition is mainly of sodium carbonate and sodium bicarbonate with ($CO_3^{2-}+HCO_3^-$) amounting to over 60% of the anions and sodium over 60% of the cations. The pH value is very high, mostly over 9.5 (Table 10).

Takyric solonetz

Takyric solonetz in China are mainly distributed in arid and semi-arid Xinjiang, Inner Mongolia, Gansu and Ningxia, Mostly in inter-sand-dune flat lands, ancient alluvial plains and dried up deltas.

The places where takyric solonetz occur are always low and flat in felief. The takyric solonetz area in Xinjiang has very deep ground water table, about 7-8 m (in Ningxia, only 3-4 m), loess-like parent material that contains some salts and much magnesium-sodium carbonate and is rather heavy in texture, with cracks on the land surface, and little or sparse higher plants, only patches of algae and lichen, etc. in moist season.

On well-developed desert solonetz, there are soil crusts with a very thin layer of dark brown algae and some light irregular multiangular cracks. Under this layer, there is a 1-5 cm thick light loamy eluvial horizon, light grey and somewhat impact; then a 1-2 cm thick red drab scaly or platy transitional soil layer, impact and breakable; further downward, an alkalic horizon heavy in texture and very compact with red drab gel coating. It appears in the shape of short column or bun, not more than 10 cm thick. Light grey fine sands and silt moving downward from upper layers fill up all the vertical cracks. The soil expands when wet and shrinks dry, with very poor permeability and very high alkalization. Then down below is the salic horizon and the parent material.

Potential salt-affected soils

The soils are mainly distributed in the arid and semi-arid regions of China, West Mongolia and the piedmonts of the Altai Mountains.

In Xinjiang, Gansu, Inner Mongolia, Ningxia and Qinghai of China, there are extensive continuous tracts of potential salt-affected soils, which are mostly distributed in piedmont diluvial-alluvial plains and ancient river terrace with vegetation of desert semi-shrubs and shrubs, which have deep plains and ancient river terrace with vegetation of desert semi-shrubs and shrubs, which have deep pulposi roots. Low vegetation coverage is the typical desert landscape.

Formerly this type of soils were sorted separately into the types of grey desert soils, brown desert soils, sierozems and grey brown desert soils, but when viewed from the angle of salt-aggected soils, all these soils are to be included in the type of potential salt-affected soils. Their properties can be generalized as follows;

a) Gravel mulch landscape … Dry and windy climate aggravates aeolian erosion, which deprives the land surface of most fine earth, leaving gravels only and forming gravel mulch landscape. In some areas even polished coating can be found.

b) Significant surface lime accumulation … Dry climate and the rerultant weak leaching stimulate formation of lime during the weathering and soil forming processes. And then lime moves up with soil water and accumulates in the surface.

c) Enrichment of soluble salts and gypsum in the subsoil … As a result of the geological processes, the soil has very high content of soluble salts and gypsum, which even forms into salipan and gypsic horizon. The salt content varies with the location, ranging between 0.3 and 4.0%, and in the salt composition $SO_4^{2-}>Cl^-$.

Currently this type of soils are used as pasture, and only in the neighborhood of some population points, some small pieces of the land have been reclaimed, however, the lack of water sources makes it very difficult to reclaim for cultivation.

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Table 10 Chemical composition of a haplic solonckak*

Depth (cm)	pH	TSE g/kg	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	K^++Na^+	ESP %
					cmol/1000 g soli					
0-5	10.0	1.42	1.45	0.66	0.18	0.03	0.08	0.21	2.02	65.29
5-20	10.2	2.81	3.18	0.24	0.40	1.01	0.34	1.03	2.59	75.60
20-48	9.8	2.10	1.77	1.09	0.45	—	0.08	0.02	3.20	68.99
48-60	9.5	1.18	0.64	0.86	0.23	—	0.06	0.16	1.51	54.35
60-120	8.7	0.70	0.12	0.62	0.23	0.11	0.06	0.19	0.83	28.01

* In 1: 5 soil-water ratio extraction; soil sampled in Liaoning, China.

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