Classification of Maritime Salt Affected Soils in Yugoslavia

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The coastal area of Yugoslavia covers more than 2000 km. It includes the area between the borderland of Italy and Albania. Along the Adriatic coast there are more than 1000 islands [17]. Under the influence of the greatest body of water, the Adriatic sea, the process of salinization is permanently carried on in this area, and by fresh water the process of desalinization of the soil also occurs.

GRACAININ [6, 7, 8, 9] was the first to deal with the problem of the maritime salinization of the islands of Yugoslavia (Pag). BLASKOVIC has since been investigating the salt affected soils of the coastal area of the Adriatic sea, for example in the valley of the river Dragonja (1949), in the valley of the Mirna river (1953), the area of Vransko Blato (mud. 1955) and in the valley of the lower course of the river Neretva (1958) [1, 2, 3, 4].

The valley of the river Rasa was researched by KOVACEVIC and he found in it a certain degree of salinity [13]. PLAMENAC [16], dealing with Ulcinjsko Polje in the coastal area of Montenegro, studied the processes of salinization and desalinization in the soils.

The saline and saline-alkali soils (slatina) of Yugoslavia occupy about 265 thousand hectares. About 230 thousand ha of such soils are in Vojvodina, and 24 thousand in the coastal area and on islands (about 9% of the total surface), while the rest, about 11 thousand hectares, is in Macedonia.

Factors of the coastal soil formation

The coastal soils of the Adriatic area developed under the influence of a great number of active pedogenetic factors.

Climate

Climate had a prevailing role in the formation of soils. According to KÖPPEN the whole coastal area, except in the high mountains, belongs to the region of climate C (moderate warm, humid climate). Still, according to KÖPPEN's climatic classification there exist certain diversities. In the south-western part of the Adriatic coast there prevails a pure aethesian climate (Csa), in the most northern part Cfa climate, and in the other parts of the area there is modified aethesian climate (Csa). In Thorntwaite's climatic classification the Adriatic coastal area belongs to the humid climate $(P)E = 64-127$ [17].

In the coastal area of the Adriatic the average annual precipitation varies between 560 mm (Vis) and 1450 mm (Krk), (Dubrovnik). The average annual temperature varies between 13 °C (Novigrad) and 17 °C (Dubrovnik). The precipitation is most abundant between October and May, and high temperatures appear from June to September. The processes of leaching and soil salinization are very important, because during the wet period salt descends and during the dry period it ascends.

For the whole Adriatic area the average annual rain factor amounts to 81 (on the border of semi-humid and humid climate). According to LANG's classification, brown soils should have formed in this area. Wind reduction of humidity must have been the reason for the formation of reddish-brown soils in the greatest part of the coastal Adriatic area. In the coastal area salted winds are characteristic (especially with north-eastern wind), which carry sea-water and cause salinization of the soil (Fig. 1).

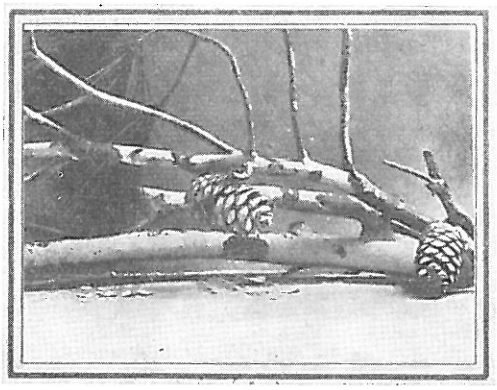

Fig. 1
Salinization caused by winds, a twig of *P. Halepensis* covered with salt (Rab)

Geological conditions

The soil of the coastal Adriatic area and islands developed mainly on upper creataceous limestone and in some cases on limestone from other periods of Mesosoic. Here and there dolomites can be found. In the central part of Istria and in Hrvatsko Primorje and Middle Dalmazia soils are formed on paleogene limestone and flish from the period of Eocene. Quarter sediments are represented by the various deluvial and alluvial sediments. These can be found in karstic areas, depressions, river valleys, etc. Fluvioglacial and moraine sediments can also be found in the valley of the Neretva river and in Grobnicko Polje. In the zone of the karst meadows we can find deluvial and alluvial sediments in the valleys of present rivers (Mirna, Rasa, Cetina, Neretva, Bojana etc.). Eolian sand loess is found in some places on the islands of Susak, Pag, Rab and in the surroundings of Zadar [16]. On the above described geological base in Hrvatsko Primorje, soils of various characteristics developed.

Relief

The Adriatic coastal area and islands present low and very variable relief. It is limited by the Dinaridi inland, which descends to the sea forming the narrow area (The Bay of Kvarner, the area at the foot of the mountain Velebit). On the other side, in the western part of Istria, in the northern Dalmazia, in the lower course of the Neretva river and around lake Skadar, the area widens to the karstic plains. On the various topographic positions various kinds of soils formed.

Vegetation

In the coastal area and on the islands of the Adriatic sea there are two vegetation regions: Mediterranean with two climatic zones, and Eurosibirico-boreamericanum with a submediterranean zone of the white hornbeam only [12]

1. The mediterranean region of vegetation covers the narrow zone of the *Adriatic coast* with *Quercus ilex* and *Olea europea*. It is abundant with maquis, meadows, ploughland, vineyards, orchards, olive-groves, etc.

a) The zone of *Orno-quercetum* ilicis appears on the degraded deep soils. In this woody zone there appear *Quercus ilex*, *Fraxinus ornus*, *Olea oleastrum*, *Laurus nobilis*, *Erica arborea*, *Myrta communis*, *Rosa sempervirens*, and in the southern part of the Adriatic coast we can find *Quercus coccifera*, etc.

b) The zone of *Pinetum nigrae* dalmaticum appears in a few places at higher levels. Besides the black pine other sorts of flora and deciduous trees grow.

2. In the Eurosibirico-boreamericanum region the prevailing type of vegetation is the submediterranean zone of the white hornbeam *(Carpinetum orientalis croaticum)*. Besides the white hornbeam there are present *Ostrya carpinifolia*, *Quercus lanuginosa*, *Acer monspesulanum*, *Quercus cerris* etc. [12].

The aforesaid vegetation, as well as the other vegetation, influenced the development of the coastal soils.

Influence of man

By cultivation and the felling of trees man has influenced the formation of soils, causing in some places erosion and the formation of bare karstic areas. Erosion by water was accompanied by eolian erosion. Cultivation and making terraces (especially on flish) upset the natural soil profile. Vegetation contributed to the new humification of eroded remnants of terra rossa or to the formation of rendzina. Karst meadows are cultivated intensively, and especially on terrains where meliorations took place, so the properties of soils in such places changed [5].

The soils of the Adriatic coastal area

Under the influence of previously analyzed factors the various types of soils and their varieties developed in the Adriatic coastal area (Fig. 2).

Climate in the southern part and on the islands is more Mediterranean, while it has more continental character in the north-western part because

of the Alps. Climate had a great influence on the formation of terra rossa. Also the main substratum influenced the formation of soil, where the characteristic types of soil are prominent. The Adriatic territory lies on karstic limestones and flish from the period of Eocenic limestones. These three

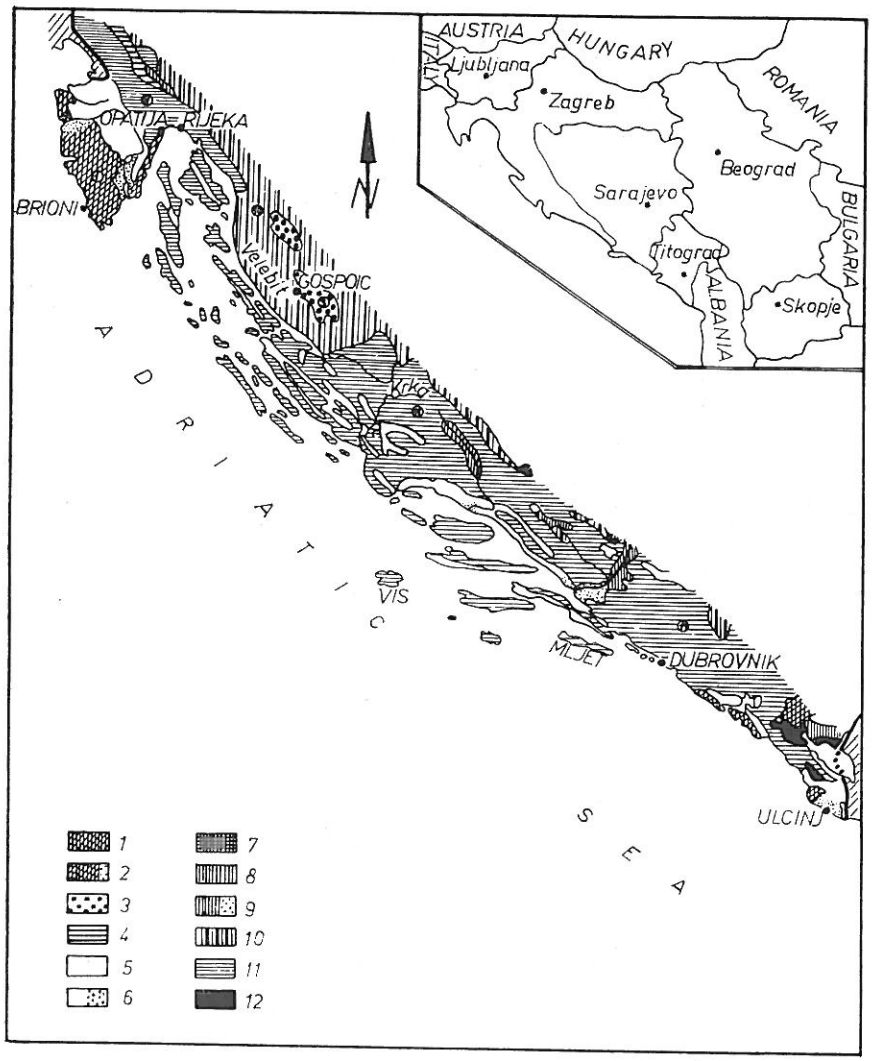

Fig. 2

Soil map of the coastal area. 1. Mediterranian red soils on hard limestones (Terra Rossa). 2. Mediterranian red soils on hard limestones (Terra Rossa) with alkali and saline soils. 3. Fern and heather podzolic soils, brown soils on hard limestones and terra soils. 4. Gray brown podzolic soils and regosols on flish and marls. 5. Regosols on flish and marls. 6. Regosols on flish and marls with alkali and saline soils. 7. Meadow and hydromorphic soils. 8. Recent alluvian deposits. 9. Recent alluvian deposits with alkali and saline soils. 10. Rendzina and brown soils. 11. Bare marls with spots of Terra Rossa and rendzina soils. 12. Acid, brown and podzolic soils

substrata differ in their properties and age. So on calcareous limestone, terra rossa and its derivates have mainly developed. On flish there developed mineralogical carbonic soils and marly rendzina. On the Eocenic limestones there developed brown soils. The bare karstic soil with some spots of terra rossa and rendzina are present on almost all the islands and in the territory of Dalmazia and in Hrvatsko Primorje and Istria [5]. Recent alluvial soils have formed in the river valleys under the influence of alluviums with various degrees of salinization. Because of this there are hydrogenic soils in the valleys [1, 5].

Causes of salinization of the coastal area

The process of salinization of soils along the Adriatic coast works under the influence of the sea. The salinity of the Adriatic sea is between 35 and 38%. To the north the salinity of the sea is lower, while it is higher in the south. The chemical composition of water from the Adriatic sea is as follows [17]:

Cations g/kg		*Anions g/kg*	
Sodium	11.81	Chlorine	21.25
Potassium	0.39	Bromine	0.092
Magnesium	1.42	Sulphate	2.97
Calcium	0.457	Bicarbonate	0.159
Strontium	0.014	Boric acid	0.130

In the Adriatic sea other elements can be found. From the above table we can conclude that the sea water contains mainly sodium and chlorine with 90% of all salts being chlorides and 80% Na Cl.

In deltas and in the river mouths along the Adriatic coast, as described by prof. BLASKOVIC for the lower course of the Neretva river, processes of maritime salinization are occurring as follows [1]:

1. Direct salinization of the soil by means of salt groundwater ascending by capillarity toward the surface, where it evaporates, leaving its salts in the soil.
2. Soil salinization by waters from the salt wells that originate by the mixture of fresh water from the karstic wells and saline groundwater.
3. Soil salinized directly by inundation with sea water.
4. Eolian salinization by wind-borne sea water (particularly on islands and along a narrow coastal band).

Classification of salt affected coastal soils

We developed a classification of salt affected soils based on the causes of salinization.

a) *Classification of maritime salt affected valleys* (Fig. 3, 4, 5)

A common characteristic of these soils is their depth and variable degree of salinity with no clear B-horizon. In the delta of the river Neretva (and other rivers of the Adriatic conflunce) occupying more than 13,000 hectares the following soils are classified on the basis of the degree of salinization [1]:

1. Alluvial-carbonate soils: slightly to medium salted (0.5—5% soluble NaCl)

2. Alluvial-carbonate soils: regularly inundated by high-tide, strongly and very strongly salted (5—15% soluble NaCl)

3. Deluvial-carbonate soils: slightly salted (0.5% soluble NaCl)

4. Mineral carbonate swamp soils: medium to strongly salted (0.5—15% soluble NaCl)

5. Organogeneous swamp soils or peaty soils (older, and younger or recent peat, medium salted (0.5—5% soluble NaCl).

Fig. 3
Arundo donax destroyed by salt (Neretva)

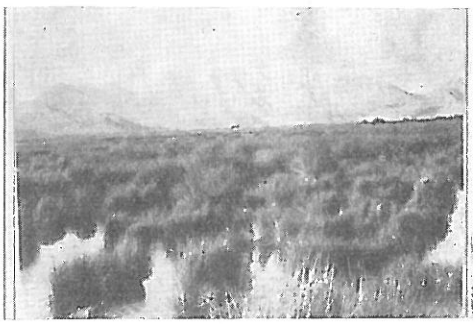

Fig. 4
Hydromorphic vegetation assoc. *Hydrocotileto Caricetum Elatae* (Neretva)

The degree of salinity of the soils in the valley of the Neretva river is stated on the principle of the Dutch chemical-biological scale regarding the concentration of NaCl in the soil's liquid phase.

As hydrogenic soils of the Neretva river contain besides the soluble salts in their solution, sufficient free Na to cause alkalinization, they are alkaline salt affected soils (chloride-solonchak).

Fig. 5
Profile of organogeneous swamp soil (Neretva)

With regard of the kind of salinization in the valley of the Neretva river we distinguish the following alkali salted soils:

a) Alluvial carbonate and deluvial carbonate soils on the lower relief positions are solonetz-like (alkalicalcic solonetz).

b) Mineral swamp soils and alluvial carbonate soils inundated by high-tide are humid soils or swampy solonchaks (alkali-calcic solonchaks).

c) Organogeneous swamp soils (peaty soils) are boggy solonchaks (alkali-calcic solonchak).

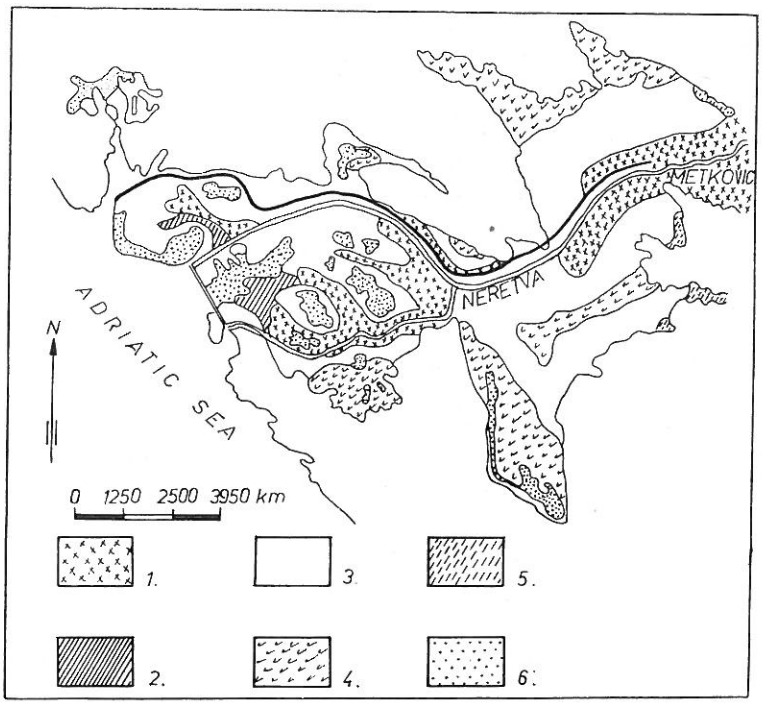

Fig. 6

The valley of the Neretva river soil map. 1. Alluvial carbonatic soil (<0.5– 5‰ NaCl). 2. Alluvial carbonatic inundated by the sea water (5—15% NaCl). 3. Mineral swamp soil (0.5—15% NaCl). 4. Organogeneous swamp soil (0.5—5% NaCl). 5. Deluvial carbonatic soil (<0.5% NaCl). 6. Lake

The above written classification corresponds to GRACANIN's classification of mineral and organogeneous swamp salt affected soils of the island of Pag.

These saline soils differ among themselves according to their genesis, mechanical composition, structure, chemical and microbiological properties and the influence of water and air. The characteristic feature of the mineral swamp and organogeneous swamp soils in the valley of the river Neretva is the formation of a gley horizon in the deeper strata. A hard mechanical composition of the soil (clay) and an abundance of humidity are the main reasons for the processes of gleyization (Fig. 6).

A similar classification to this of the valley of the Neretva river was given by PLAMENAC in Ulcinjsko Polje on an area of more than 2000 hectares

(1964). With regard to degree and kind of salinity, PLAMENAC classified the soils of Ulcinjsko polje into three salinity classes. Saline-alkali soils were separately grouped.

Here is the classification according to PLAMENAC [15]:

1. Slightly salted soils. Silt, silty-clay and silty loams containing sulphates.

2. Medium salted soils. Clay, silt and sandy loams containing chlorides and sulphates.

3. Strongly salted soils. Clays, silty clays and silts with chloride and sulphate-chloride regimes.

Hydromorphic saline-alkali soils formed the separate group and were chloride-solonchaks [15].

The processes of salinization and desalinization in all the valleys of the rivers flowing into the Adriatic sea are active during the wet and dry periods. Desalinization takes place during the winter rainy months, while salinization takes place during the dry summer months. In the dry period of the year water remains only in deeper depressions where hydrogen-saline-alkali soils developed.

b) *Classification of salt affected soils on islands and in the coastal area*

The salinization of islands was worked out by GRACANIN on the island of Pag [7]. The author stated that climate was the most prominent soil-forming factor on the island of Pag. It was prominent on the stony soils and meadows, while on muddy ground the formation of soil was connected with special water and vegetation conditions. The dynamics of a soil are influenced by its physical and chemical properties, the original substratum, relief, etc. Climate, predominantly humid and warm in the coastal area, was a major factor in the formation of the soils. But certainly, a specific character is given to these soils by salted winds, causing a permanent salinization in the

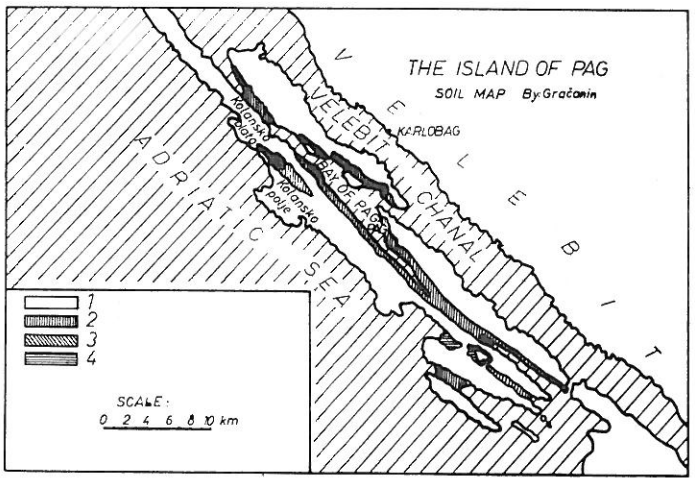

Fig. 7

The soil map of the Island of Pag. 1. The stony soil with brown solonetz soil. 2. Solonetz. 3. Mineral solonchak soils. 4. Organogeneous swampy solonchak soils

coastal area and on islands. There were two main processes in developing the coastal salt affected soils: leaching and salinization.

In regard to genesis of soils, M. GRACANIN divided the soils of the Island of Pag into four groups [7]:

1. Stony soils (brown solonetz)
2. Dry meadow soils (solonetz)
3. Humid meadow soils (solonetz)
4. Muddy soils (muddy solonchak)

According to the kind of salinization, the same author described the above classification as follows:

a) Stony soils have the character of an undeveloped skeletal brown solonetz because of their shallowness and permeability.

b) Dry meadow soils are saturated by ions of alkali and calcium, and they contain a small quantity of readily soluble alkali salts. The author included them in the alkali-calcic solonetz group.

c) Humid meadow soils contain in their solution a high concentration of alkali and Ca ions, so they were placed in the group of alkali-calcic solonchaks.

d) Muddy soils are rich in readily soluble salts and they were placed in the group of organogeneous swamp soils (alkali-calcic solonchaks).

It is not possible to put all these soils on the soil map because of the map's small scale, so they are grouped with the bare karstic soils along with some spots of terra rossa and alluvial or hydromorphic soils (Fig. 7).

This classification of salt affected soils of the Island of Pag can be applied to other terrains of the coastal and insular karstic area, because the natural conditions are the same.

Methods of reclamation of Maritime salt affected soils

Reclamation of salt affected soils of the Adriatic coastal area can be brought about through some complex measures.

1. In the river valleys where a process of salinization is working permanently, it is necessary to undertake desalinization by means of various technical measures like: the regulation of the course of a river, protection from waters of springs and mountains, building of polders, protection from seawater, internal drainage (in open and closed canals), leaching, irrigation in dry periods of the year etc. Draining in deep canals can lower the level of salted water and prevent soil salinization. The problem of the drainage of brackish surface water can be solved in the same way. Because of favourable climatic conditions (abundance of precipitations in winter) it is possible to accumulate water in some places on islands and on the coast for the leaching and irrigation of salted soils. In the wider valleys, waters from rivers can be used for the purpose of desalinization and irrigation (Mirna, Rasa, Neretva, Bojana etc.).

2. It is advisable to add a certain quantity of sulphur or gypsum to carbonate salted soils for the purpose of desalinization, and this must be done before the beginning of the dry period [1].

3. Because of salted winds it is necessary to re-afforest karstic land. *Pinus nigra* and *Pinus halepensis* have shown many advantages in the coastal area on the karstic land. *Quercus ilex* and *Olea europea* are also suitable.

Tamarix and *Arundo donax* are the most suitable vegetation for meadow areas. In Italy there are *Eucalyptus* which grow very quickly and resist salted winds. But in our country it was not satisfactory. It would be necessary to select a new kind of *Eucalyptus* for our conditions.

4. Where the concentration of salt in the liquid phase of a soil is rather high and increases because of permanent salinization, salt tolerant crops must be grown. On this terrain various halophilic plants might be cultivated [1, 7].

5. Coastal soils are rich in potassium, calcium and magnesium, so these elements don't need to be applied. They contain only a small quantity of phosphorus and it must be added to the soil for plant nutrition. Sulphur additions are not required for plant nutrition. In some soils of the coastal area we find a small quantity of nitrogen and in some soils a large quantity of it. In hydromorphic soils rich in organic matter we find a considerable amount of nitrogen. Where it is insufficient we must add it to the soil in the form of stable or green manure. It is possible to increase the concentration of alkali in the liquid phase of a soil by the application of some nitrogenous fertilizers, especially $NaNO_3$ and $CaCN_2$, because of their alkali reaction. Care should be taken when dressing alkali salted soils with nitrogenous fertilizers.

6. Maritime salt affected soils in Yugoslavia have not yet been microbiologically investigated.

By carrying out the mentioned soil reclamation (physical, chemical and possibly microbiological) favourable conditions may be attained for plant production on the coastal and insular areas of the Adriatic sea.

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