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in

Zdruli P. (ed.), Steduto P. (ed.), Kapur S. (ed.).
7. International meeting on Soils with Mediterranean Type of Climate (selected papers)

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 50

2002
pages 31-36

CHAPTER I

SOIL GENESIS, CLASSIFICATION AND CARTOGRAPHY

SOILS AND VEGETATION OF COASTAL AND WETLAND AREAS IN NORTHERN ADRIATIC (NE ITALY)

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Introduction

Soils of the coastal areas present generally little evolution, since they are affected by erosional-depositional events, oscillating water-table, spatial variability of texture, carbonate and organic matter content (Rabenhorst, 1997; Stolt et al., 2001). Leaching, decarbonation, brunification, gleyzation have been recognised as the most active soil forming processes in these areas in temperate regions (Mancini, 1956; Wright, 1992; Moody and Graham, 1995, Lesovaya, 1998). Also anthropic intervention contributes in modifying soil development: sand and water extraction, terrain levelling, tourism enhancing, land use changing, all of these contribute to new environmental conditions that may affect pedogenesis. Correspondingly, the natural vegetation of these areas may be subjected to change with changing of environmental conditions.

Similar modifications have been recorded recently in coastal and wetland areas of North-East Italy (Marchiori and Sburlino, 1996; Barbieri, 1997; Iaconcig, 1998; Bini et al., 2001), where land reclamation and changes in management in the last 100 years determined new conditions for the soil genesis and the development of the vegetation cover.

The objectives of this work were:

- to examine the soil distribution in these sensitive areas, which constitute examples of pedosites subject to disappear with changing of environmental conditions;
- to relate soils and phytocoenoses with peculiar ecological characteristics; and
- to indicate a trend of pedogenesis which might be applied to areas subjected to water-table or sea level variations, in consequence of hypothetical climatic changes and in relation to their future management.

Materials and Methods

Site location. The investigated area is part of the perilagoonal belt located in the north-eastern part of Italy, between the river Isonzo and the Venice lagoon (Fig.1). Geologically, it is composed of Holocene mainly sandy alluvial materials. All over the Holocene, the coastline was close to the present (Marocco, 1989). However, subsidence, eustatism and variations in river-transported solid materials determined a peculiar topography, with depressed wetlands and hydromorphic areas alternating with drier ones, located in more elevated places.

Figure 1. Location of the studied area. Inset: indication of the sites investigated.

Data elaboration on the basis of the bioclimatic indexes proposed by Rivas-Martinez et al. (1997) shows that the present climate in the study area is temperate submediterranean sub-humid. The mean annual temperature is 14°C. Mean annual precipitation ranges from about 950mm in the southern part and 1,035mm in the northern part. According to the Soil Taxonomy (U.S.D.A., 1998), the calculated Soil Temperature Regime is mesic; and Soil Moisture Regime is variable from aquic to udic-xeric depending on local topographical conditions.

The vegetation of the area is characterised by the mutual influence of different chorologic elements: C-European, Mediterranean, Orophilous and Illyric (Sburlino, et al., 1995; Marchiori and Sburlino, 1996). Such a compenetration, together with the peculiar environmental conditions, is responsible for the coexistence of plant communities with both a C-European and Mediterranean trend. At the same time, the local topography determines the presence of the edaphoxerophilous series (*Fraxino orni-Querceto ilicis* sigmetum) at some sites, and the edaphohygrophilous one (*Carici elongatae-Alneto glutinosae* sigmetum) at other ones.

Among the different phytocoenoses in the investigated area, the most interesting are the hygrophilous natural and semi-natural fens and meadows, like the endemics *Erucastro-Schoenetum nigricantis* and *Plantagini altissimae- Molinietum caeruleae*, growing on neutral to subalkaline soils enriched in organic matter. The latter association is common in areas where water- table is close to the surface, and the continuous agricultural management (mowing, manuring) enhances preservation of these prairies. Progressive abandonment determines littering, auto-manuring and development of common shrubs, and successively wood vegetation.

Field and laboratory analyses. A preliminary soil survey was carried out in order to outline the soil distribution pattern in the investigated area. Afterwards, thirty-two sites located in different topographical position were selected (Fig. 1). At every site, a soil profile was excavated and described according to the national guidelines (Sanesi, 1977). Samples of each horizon were collected for laboratory analyses.

Soil samples were air-dried and passed through a 2 mm sieve. Standard laboratory methods (MIRAAF, 1994) were carried out on the fraction <2 mm, and included: particle-size distribution (pipette), readily oxidable organic carbon content (Walkley-Black); pH (1:2,5 soil-water ratio), cation exchange capacity (triethanolamine and $BaCl_2$ buffered at pH 8.1), total carbonates (gas-volumetric), electric conductivity (1:2,5 soil-water ratio), and available water capacity on not saturated soils (Salter *et al*., 1966).

Correspondingly, at the same sites a phytosociological survey was carried out, following the sigmatist method of the Zurich-Montpellier school (Gèhu & Rivas-Martinez, 1981).

Results and Discussions

A summary of the physico-chemical properties of the soils investigated is reported in Table 1. Full information on soil and vegetation data is available from the authors.

The soils examined are scarcely differentiated, coarse-textured and present subalkaline reaction. Depending on the site location and the soil kind, total carbonates range from 34.80% in mineral soils of the northern part, and 2.80% in the southern part, because of the different lithological composition of the hydrological basin. At the same sites, the pH increases with depth, as well as the carbonate content, as influenced by the parent material.

The organic matter content varies widely, ranging from 24.60% in organic horizons of wetland areas, and 0.19% in the coarse-textured C horizons. The cation exchange capacity presents low to very low levels, ranging from 13.4 cmol(+)/Kg in organic horizons to 0.2 cmol(+)/Kg in sandy materials. Both organic matter and cation exchange capacity, moreover, decrease with depth, as expected the latter being dependent on the former. The electric conductivity (mean 1.09 mS/cm) increases with depth, and decreases with distance from the coast. The available water capacity is generally low, ranging from 83 mm in deep soils to only 16mm in shallow, sandy soils.

Table 1. Selected soil properties of the studied soils. (Mean values and ranges).

Soil properties	**Mean**	**Range**
Texture	Sand 77	98-68
%	Silt 15	25-2
	Clay 4	8-0.5
pH	8.05	8.36-7.49
O. M. %	5.77	24.60 – 0.19
Total Carbonates %	14.65	34.80-2.80
C.E.C. cmol(+)/Kg	2.67	13.4-0.2
E.C. mS/cm	1.09	8.5-0.05
A.W.C. mm	47	83-16

Dune soils. The soils of the most recent dunes are shallow, sandy, calcareous, mesic *Typic Xeropsamments* or *Typic Udipsamments*, depending on local topographical conditions, and have very low organic carbon content and scarce horizon differentiation. The vegetation cover is represented by xerophilous meadows such as the discontinuous therophytic *Sileno coloratae-Vulpietum membranaceae* with pioneer character, and the perennial, nearly continuous, *Tortulo-Scabiosetum*.

The inner, more stable dunes host more developed soils, with some characteristics (for instance, texture, reaction, and carbonates) close to the previous soils, however, they are more thick and have better horizon differentiation with blocky structure, higher organic carbon content and higher AWC. Depending on the Soil Moisture Regime, these soils are classified as *Typic Haploxerepts*, *Arenic* and *Typic Eutrudepts*.

Consequently, vegetation evolves towards more structured forms, such as medium and high shrub communities referable to *Prunetalia spinosae* (e.g. *Crataegus monogyna, Cornus sanguinea, Ligustrum vulgare, Rubus ulmifolius*), and culminates in the edafoxerophilous forest dominated by holm-oak (*Fraxino orni-Quercetum ilicis*).

It should be pointed out that the latter association represents a durable community with edaphic determinism. Indeed, for the peculiar geomorpho-edaphic conditions (particularly depth of water-table, texture and AWC) there is no possibility of any evolution towards the climatic vegetation of the Po Plain (*Asparago acutifolii-Quercetum roboris*).

Interdune soils. The soils of the interdune lowlands present characters close to the shallow dune soils (coarse texture, subalkaline reaction, scarce horizon differentiation), but with nearly permanent water saturation, reducing conditions and a slightly saline water-table, at least in soils closer to the coastline.

Therefore, under an aquic soil moisture regime, redoxymorphic features are developed, and organic matter accumulation may occur. Under these conditions, pedogenesis progresses very slowly, and most soils are classified as Entisols (*Mollic* or *Typic Psammaquents*; and *Aquic Udipsamments*). The vegetation cover in this wet habitat is referred to as *Soncho maritimi- Cladietum marisci*, or as *Eriantho-Schoenetum nigricantis*, depending on the quality and level of the water-table.

Inner wetland areas present counteracting aspects, since they are of interest both as regulators of hydrological conditions (agricultural lands) and for preservation of biodiversity (natural and semi-natural areas). They are characterised by soils with coarse-loamy texture, subalkaline reaction, accumulation of organic matter, and are located in a pedoclimatic context with fresh water-table close to the surface.

This condition of nearly permanent saturation limits percolation and water tranfer. Therefore, the evolutionary trend is strongly limited by water persistence, and organic soils (*Hydric* and *Terric Haplofibrists*) or organic matter-rich mineral soils (*Thapto-Histic Endoaquolls, Aeric Endoaquents*) prevail in such nearly saturated areas.

The more the water-table level decreases, the more mineral components prevail over organic materials: Mollisols and Entisols (*Oxyaquic Hapludolls* and *Mollic Udifluvents*) are typical soils developed in seasonally saturated conditions, in areas with higher topography.

Consequently, vegetation changes, in function of the water-table level and the nutrient content, from the hydro-hygrophilous *Phragmition communis* reeds to fens and wet meadows with different plant communities belonging to *Caricion davallianae, Magnocaricion elatae* and *Molinietalia caeruleae* (all of them with high cover of grasses) and further to the marshy willow shrub (*Frangulo-Salicetum cinereae)*, and to the black alder wood (*Carici elongatae-Alnetum glutinosae*).

Conclusions

The properties and development of the studied soils change with environmental changes. Somewhat like a soil catena occurs, reflecting the topography differences and the water-table oscillations between uplands and lowlands. Soils developed on uplands (Entisols and Inceptisols) are commonly better drained than adjacent topographically lower areas, where Mollisols and Histosols occur.

These are frequently flooded or have their surfaces close to, or even below, the water-table. Under saturated conditions and in the presence of organic matter, redoximorphic features (gley or pseudogley) and a peat layer may develop, both at surface (Histosols) and buried (Mollisols).

The general trends for soil formation and evolution may be summarised as follows:

a) Dune soils

Typic Xeropsamment **Typic Udipsamment** **Typic Haploxerept** **Arenic Eutrudept** **Typic Eutrudep**

b) Interdune soils

Mollic, Typic Psammaquents **Aquic Udipsamments**

c) Wetland soils

Hydric, Terric Haplofibrist **Thapto-Histic Endoaquoll** **Aeric Endoaquent** **Oxyaquic Hapludoll** **Mollic Udifluvent**

In conclusion, the degree of soil development (maturity) depends on the soil water regime. Landscape configuration and its associated hydrological characteristics affect morphological (e.g. horizonation), physical (e.g. texture, structure) and chemical (e.g. fertility, electric conductivity) evolution of soil profiles.

The main soil-forming processes are littering and gleyzation (at wet sites), humification, slight leaching and decalcification (at drier sites). Correspondingly, as a consequence of changing pedo-environmental conditions, the natural vegetation evolves from annual to perennial herbs and woods, following site-specific trends: a *Fraxino orni-Querceto ilicis* sigmetum at xeric sites, and a *Carici elongatae-Alneto glutinosae* sigmetum at wet sites. Moreover, wetland reclamation and soil drainage improvement may determine a drastic variation of the land cover and the related pedogenic trend, as observed by Bini et al. (2001).

Finally, tectonic activity (e.g. eustatism, subsidence) in the area does not play a major control on soil evolution, at least on small scale. Despite the complex geomorphology, soils can be correlated over the whole region, and this model of pedogenesis may be applied to other similar areas, and could impact a number of management decisions.

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