Geopedological processes in Doñana National Park (Spain)

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Introduction
The weathering processes and soil formation developed on the Litoral Aeolian Sand Sheet of Doñana (Huelva, Spain) (Borja et al., 2014) have been recently studied by Díaz del Olmo et al. (2014) and Recio et al. (2009, 2011) in situations related to the geomorphological situation.

The most relevant morphological and physico-chemical characteristics of a soil profile developed on phytostable dunes by a juniper forest (Juniperus turbinata) are analyzed in this paper. Its presence is verified at least from the aerial photo of 1956 (profile SOJ-2) in the «sabinar Ojillo», located in high-dry savin forest (Bejarano et al, 2010, Cámara et al., 2013) (Fig. 1). The purpose is to know how the pedogenesis is responsible for this pedogenesis, and the evolution experienced by the physicochemical parameters with the depth show an intense lateral washing of sand (sand washing). The different patterns of distribution of the medium sands along the profile could be used for the differentiation between different environmental conditions.

Materials and methods
The SOJ-2 soil profile (Fig. 2 and 3) has been described and classified according to FAO classification systems (1977 and 1989). Its physicochemical and mineralogical characterization has been carried out following the usual methodology of our laboratory (Brindley and Brown, 1980; Dearing, 1999; Duchaufour, 1975; Guitián and Carballas, 1976; Mehra and Jackson, 1960; Montealegre, 1976; Munsell, 1990; Parfenoff, and Pomerol, 1970; Pinta, 1971; Sims and Haby, 1971; Soils Survey England and Wales, 1982; USDA. 1973).

Results and discussion
The SOJ-2 soil profile appears as a powerful sandy soil, open up to about 300 cm. of depth (Table 1), and crowned by dark horizons brownish of 90 cm thick, with characteristics close to the isohumic soils of Duchaufour (1984).

Due of its physical-chemical characterization, it presents a morphology corresponding to the Arenosols group of FAO (2015), but with the presence of a horizon of accumulation of organic compounds rich in iron and manganese, protic iluvial characteristics, which makes it be classified as Arenosol chromic by FAO (2015).

This profile shows a sequence of superficial horizon type A (A11 and A12) of 30 cm. and about 60 cm of thickness for the accumulation horizons B (B11 and B12). From the 100 cm, the C horizons acquire typical morphological characteristics of sands dune studied in other soil profiles by Diaz del Olmo et al. (2014) and Recio et al. (2014).

The content of organic carbon (C) is only detected in appreciable amounts in the superficial 15 cm (1.25%); the ignition loss shows decreasing values along the profile, maximum in these 90 cm colored horizonts (up to 1.38%), an elaborated organic matter translocated under the conditions of neutral pH values (around 7), and a practically non-existent salinity (Table 1). The highest humidity values coincide with these same maximum values.

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The apparent density becomes greater in the bottom of the profile, given the thickness of sands developed above, coincident at the same time in a lower porosity (around 36%). The hydraulic conductivity values always show drainage values very fast and without appreciable differences along the profile (Cámara et al., 2013).

As a direct measure of the weathering processes the levels of iron (Fe) and manganese (Mn) dithionite show these three well differentiated parts of the soil profile, as well as the presence of the B horizon mentioned above. In the same way, the magnetic susceptibility accompanies these values, being maximum in this last horizon \((152 \times 10^{-8})\) (Table 2).

Table 1
Soil profile (SOJ-2) general characterization

| Profile SOJ-2 Depth (cm) | Colour (d) | Colour (w) | Hum. | OM ign. | C | OM | pH \((\text{H}_2\text{O})\) | EC \((\text{mho/cm})\) |
|-------------------------|------------|------------|------|---------|---|----|----------------|------------------|
| 0–15                    | 2.5 Y 4/4  | 10 YR 3/2 | 0.50 | 1.80 | 0.73 | 1.25 | 7.6 | 0.11 |
| 15–30                   | 2.5 Y 4/4  | 10 YR 3/2 | 0.60 | 1.48 | 0 | 0.75 | 7.5 | 0.11 |
| 30–60                   | 2.5 Y 4/4  | 10 YR 2/2 | 0.57 | 1.44 | 0 | 0 | 7.4 | 0.1 |
| 60–90                   | 2.5 Y 4/4  | 10 YR 2/2 | 0.56 | 1.38 | 0 | 0 | 7.3 | 0.11 |
| 90–120                  | 10 YR 4/4  | 10 YR 3/4 | 0.41 | 0.93 | 0 | 0 | 7.2 | 0.11 |
| 120–150                 | 10 YR 5/6  | 10 YR 4/4 | 0.29 | 0.62 | 0 | 0 | 7.2 | 0.08 |
| 150–180                 | 10 YR 6/6  | 10 YR 5/6 | 0.19 | 0.48 | 0 | 0 | 7.2 | 0.06 |
| 180–210                 | 2.5 Y 7/6  | 10 YR 4/6 | 0.14 | 0.32 | 0 | 0 | 7.3 | 0.06 |
| 210–240                 | 2.5 Y 7/6  | 10 YR 5/6 | 0.11 | 0.29 | – | – | 7.2 | 0.05 |
| 240–270                 | 2.5 Y 7/6  | 2.5 Y 5/6 | 0.12 | 0.31 | – | – | 7.1 | 0.06 |
| 270–300                 | 2.5 Y 7/6  | 2.5 Y 5/6 | 0.15 | 0.37 | – | – | 7 | 0.06 |
Table 3 contains the granulometric characterization. On the surface the most represented sands correspond to the modal class of the very fine sands diameter (66.35%); in depth this dominance does not seem to be so clear, since the sands of medium diameter are equally represented. However, in the distribution of these sands it seems to distinguish proper weathered phases (with increase of the medium fractions up to 90 cm depth), of others erosion kind with patterns of distribution in the inverse of these same fractions.

Unlike this is different in the content of fine particles (silt and clay) that from 13.95% in surface, it decreases evenly in depth, and there is no accumulation of these in B horizon, indicative of the intensity with which the washing lateral processes take place (Fig. 4).
The presence of clay-sized particles has only been able to be analyzed in the superficial horizons, where it appears in very small quantities close to 2.5%, but these levels are duplicated at the depth of 90–120 cm, forming the incipient B horizon. This mineral clay is vermiculitic, with maximum values of 35% in the B11 (60–90 cm), and only 9% in higher layer; at 210 cm it is almost non-existent (Table 4).

**Conclusion**

The phytostability that Juniperus turbinata offers to the litoral aeolian sand sheet of Doñana opposite to the intense wind dynamics that affect them would be the responsible for a pedogenesis of one meter thick, with dark colour and the formation of a soil type chromic Arenosol with protic iluvial characteristics.

The evolution experienced by the physicochemical parameters with the depth, show the intense lateral washing of sand (sand washing) that takes place, the isohumic features that it shows in its upper part, the washing and accumulation in depth of a clearly cumulative level of fine particles rich in organic matter, iron and manganese, and high values of magnetic susceptibility and soil moisture.

The different patterns of distribution of the medium sands along the profile could be used for the differentiation between phases of strong wind activity, as opposed to others of clear phytostability and pedogenesis.

**References**

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