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Soils of Barbués and Torres de Barbués, Ebro Basin, NE Spain

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Abstract

Irrigation is needed for profitable agriculture in the central Ebro valley, one of the driest regions in Europe. In this region, aridity and outcrops of saliferous strata induce soil salinity in some irrigated districts. We present a soil map of two municipalities (about 32 km^2) coping with soil salinity and currently changing their irrigation from flood to pressurized systems. The 1:25,000 scale map displays 27 Soil Series following the Soil Taxonomy approach and records local pedodiversity for the first time. The scale of the map and its delineation on orthophotographs enables users to locate each agricultural plot (typical size ~1 ha) and to assign the soil information relevant for irrigation, and then a Soil Phase for salinity. Saline soils occur in irrigated areas totaling 24% of the total surface of the two municipalities studied. The salinity mapping plus other soil features used for map unit definition (texture, stoniness, and available water holding capacity), allowed recommendations about the design of irrigation system enhancements.

Keywords: USDA Soil Taxonomy; pressurized irrigation; soil salinity

1. Introduction

Improving water use and management is a goal of agricultural and environmental policies worldwide. Due to the aridity of much of its territory, Spain has the largest irrigated area in Western Europe, with 38,100 km^2 (FAO, 2014). Irrigation, needed to guarantee agricultural production, accounts for over 75% of water consumption and involves about 13% of the agricultural lands, one third of which is still irrigated by flooding (INE, 2008). The Spanish Government promotes a change to pressurized irrigation and other modernization measures for about two million irrigated hectares in order to save water (Lecina et al., 2010). Adequate water management is essential to preserve soil and water in semiarid areas such as the central Ebro River Basin, NE Spain, with a mean ET_0 of 1315 mm and annual rainfall of 350.3 mm in Zaragoza from 1941 to 1991 (Faci & Martínez-Cob, 1991).

Modernization measures addressed to items such as new canals, dams and more recently web sites, are much more politically relevant than items such as soil maps that need field work conducted by trained personnel. However, overlooking of soil has led to the failure of heavy investments in some irrigated districts of the Ebro valley as well as in other areas around the world. Scientific knowledge of soils can result in maps which can be tailored for specific applications.

Soil properties are often estimated and represented at regional or global scales (Dijkshoorn et al., 2005; Aksoy et al., 2016). More detailed soil maps can provide a knowledge base for agricultural management and more efficient use of natural resources. In order for the map to be usable by farmers, technicians, environmentalists, and designers of irrigation systems, the scale and presentation of the map must allow the recognition of at least the unit of management; in the Mediterranean region and other areas of the world management units are often < 1 ha.

In the semiarid lands of the central Ebro Basin irrigation faces two main problems, soil salinity and characteristics of the parental materials such as horizontality of strata, interbedded saliferous and sodic materials (Lebrón, 1988), and poor deep drainage. This situation contrasts with other irrigated districts around the world suffering from problems like salinity of irrigation water, difficult regional drainage, or sea water intrusion.

Saline soils in the central Ebro Basin constitute a significant percentage of agricultural areas (Ayers et al., 1960; Herrero & Aragüés, 1988; Toth et al., 2008; Daliakopoulos et al., 2016), requiring mapping and monitoring to avoid environmental and economic damage. Different approaches have been adopted in the region for mapping and monitoring soil salinity by Betrán (1986), Rodríguez-Ochoa et al. (1989), Díaz & Herrero (1992), and Herrero &Pérez-Coveta (2005), among others. Soil features together with land leveling that brings saliferous geological materials to the surface pose difficulties for transforming rainfed into irrigated agriculture. Moreover, a common drawback in arid areas changing to new irrigation technologies is the fading of farmers' knowledge, as traditional systems are changed to industrial agriculture.

In this context, the production of soils maps based on soil-forming processes (Ubalde et al., 2011; Brevik & Hartemink, 2013) can easily take into account soil factors relevant to irrigation system design and improvement. Describing and naming soils according to standard and widely accepted criteria, e.g.: Soil Taxonomy (Soil Survey Staff, 1999) enables the sharing of experience and the information exchange needed when dealing with new irrigation technologies. Moreover, soil surveys based on a comprehensive taxonomy at detailed scales are required for designing irrigation systems and for subsequent in-field assessments.

This work presents a municipal soil map based on Soil Taxonomy to show the diversity of soils in the area and highlighting soil properties of interest for agricultural management of irrigation districts. This 1:25,000 map displayed over aerial photograph is intended to help stakeholders' choose the kind of irrigation upgrade to increase water use efficiency and to meet societal environmental demands. The scientific foundation of the map will make deriving other specific maps easier when required for future purposes.

2. Study area

The study area lies in the Ebro Basin and consists of the municipalities of Barbués and Torres de Barbués (Figure 1). The area includes 3158 ha (3366 ha total) of agricultural land, from which 91% (2877 ha) is irrigated with water of low electrical conductivity diverted from Pyrenean rivers through the Monegros canal. The remaining 208 ha are urban areas, Flumen River, and other nonagricultural areas. Irrigation effluents and return flows go to the River Flumen that is the natural drainage for the area. The low terraces of the River Flumen have been irrigated for at least four centuries by traditional inundation system. From the 1950s, the years when the biggest irrigation works were being constructed in the basin by the Government, leveling and irrigation schemes extended in the region outside the river terraces. Most of the study area at present is changing to pressurized systems. The main irrigated crops are alfalfa, barley, corn, rice, sunflower, wheat, and rye-grass. Rice is predominant only in salinity prone areas.

Elevation ranges from 320 to 390 m a.s.l. Climate is semiarid, with a mean annual temperature of 13.6 ºC, a mean annual precipitation of 341.2 mm, and the mean annual reference evapotranspiration is 1203.6 mm, from data recorded in Grañén weather station from 2003 to 2016 (Figure 1). The soil temperature regime is thermic and the soil moisture regime is aridic or xeric according to Soil Survey Staff (1999).

According to the geological map (Sanz et al., 1991) most of the study area (83%) is covered by Quaternary materials which include Flumen River terraces, degraded glacis, alluvial-colluvial sediments, and valley bottom deposits. Materials of Miocene age cover a 17% of the area and consist of alternating horizontal strata of lutites and sandstones, which are often saliferous. The main geomorphic processes are controlled by the accentuated seasonal contrast, scarce vegetation cover, poorly developed soils, strong mechanical erosion, and transport of detrital materials (Rodríguez-Vidal, 1986).

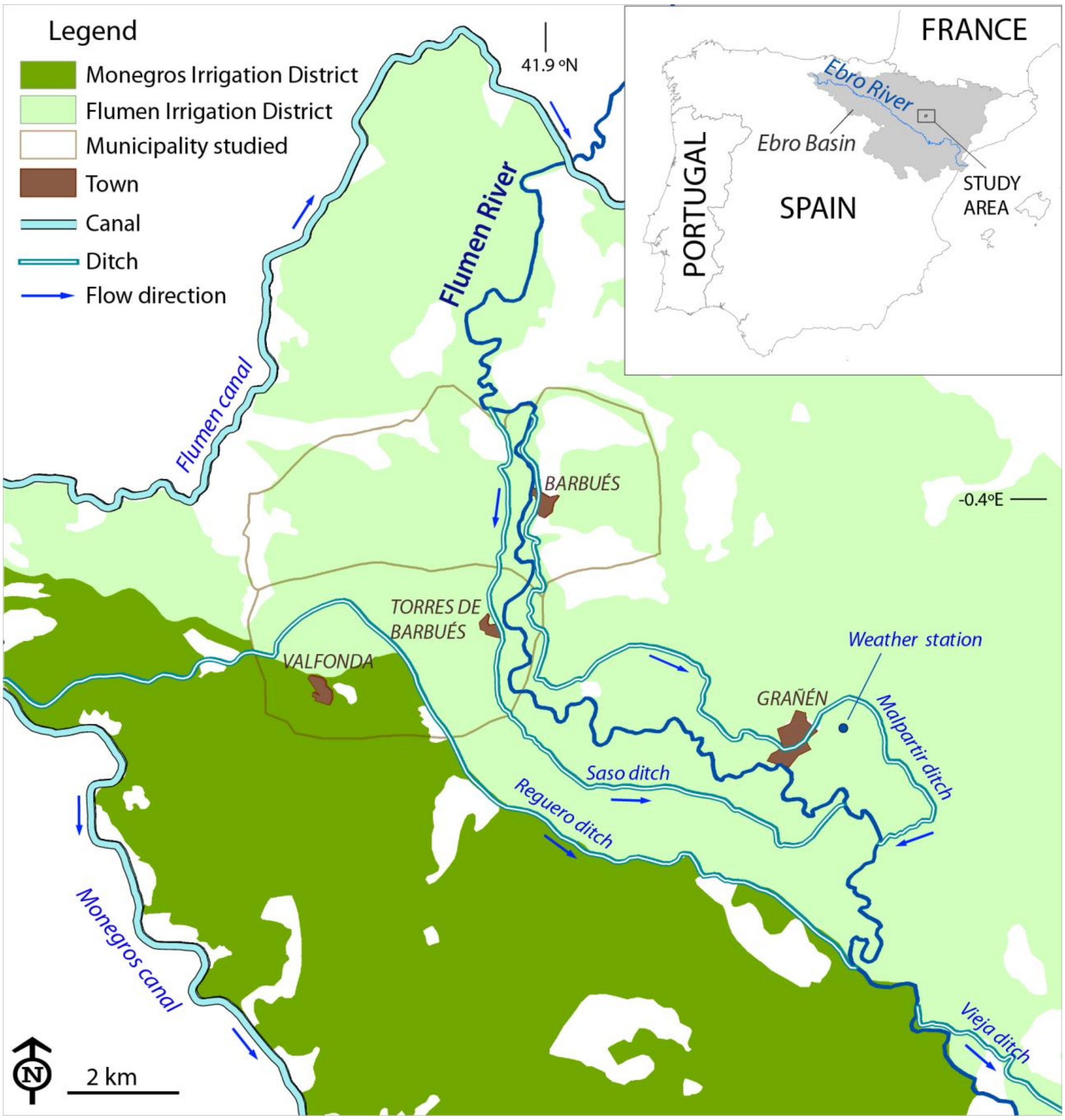

Figure 1. Location of the two municipalities studied and main irrigation elements in the area.

3. Methodology

The soil survey (Nogués, 2002) started with stereoscopic photointerpretation of black and white aerial photographs at 1:20,000 scale taken in June 1990 and was followed by field work. The main geomorphic units were delimited based on the Mapa Geológico Nacional

(MAGNA) geologic map at 1:50,000 scale and the available digital terrain model obtained from the National Geographic Institute with a pixel size of 25 m. Representative soil profiles were described over the four geomorphic units in pits dug with a backhoe up to 2 m deep or to the lithic or paralithic contact, and classified according to Soil Taxonomy. The soil survey data and the geomorphic units were integrated to compile preliminary map units over prints of aerial photographs enlarged to 1:10,000 scale. The soil map units are consociations and complexes, following the guidelines of Van Wambeke & Forbes (1989).

The main soil properties considered were salinity, water retention capacity, coarse fragments at the soil surface, and textural class of the upper soil horizon. Soil salinity was determined for geomorphic units prone to salinity by carrying out an electromagnetic induction survey (Nogués et al., 2006).

Available water holding capacity and texture were determined in soil samples collected from pits and complemented with 217 auger holes (up to 1.5 m deep) as auxiliary soil data (soil color, feel texture, penetrability, compactness, moisture, etc.) described in the field in order to locate and verify boundaries between map units. The density of soil observations was one per 11 ha.

The polygons were transferred on the screen over the orthophotographs from 1997 in a geographic information system ArcGIS®. A high resolution Digital Terrain Model (DTM) generated from airborne LiDAR data (absolute vertical accuracy of 0.20 m; density of 0.5 points per square meter) was used to check the elevation of the geomorphic units.

Data from lab and field analyses of soil samples and descriptions of the representative soil profiles are available in Nogués (2002). Three maps of interest for irrigation were derived: salinity, available water holding capacity up to 1.5 m depth, and texture of soil surface layer plus coarse components.

4. Results and discussion

4.1. Geomorphic units

The main geomorphic units (Figure 2) of the two municipalities studied are listed in Table 1. Bottoms include low lying areas, relative to the other geomorphic units, and consists of valley bottoms and depressions where water flows can accumulate salts. Terraces of the Flumen River are covered by small sized but highly productive orchard plots. A variety of planar surfaces of different origin and lithology can be found in the platforms (Rodríguez-Vidal, 1986; Nogués, 2002). The slopes connect the bottoms with platforms and terraces and favor the mobilization of soluble salts from the underlying saliferous lutites, especially after soil disturbance caused by recurrent levelling earth works in the area.

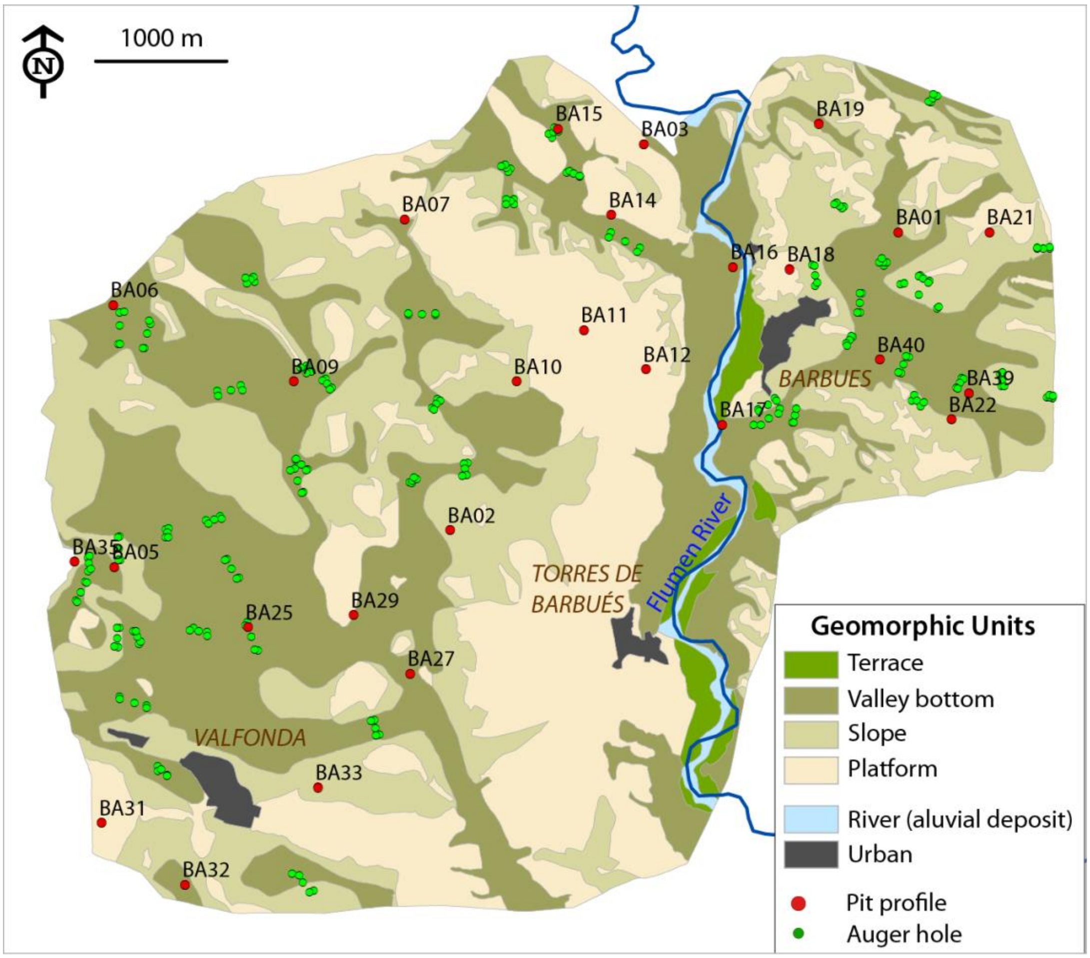

Figure 2. Geomorphic units mapped in the study area with the soil profiles used for defining soil Series, and the auger sampling sites for the specific soil salinity survey.

Table 1. Characteristics of the main geomorphic units of the study area.

Unit	Area extent		Definition	Materials
	ha	%		
Platform	969	29.5	A level or nearly level surface (Bates & Jackson, 1990)	Any material, including limestones, sandstones and gravels
Slope	1025	31.2	Inclined surface (Bates & Jackson, 1990)	Colluvial and alluvial sediments, frequently saliferous
Terrace	56	1.7	Planar surface that remains after the river, which formed it, incised its former valley floor (Goudie, 2004)	Sandy and silty sediments of the Flumen River
Bottom	1233	37.6	Floor of the valleys and depressions (Bates & Jackson, 1990)	Fine and often saliferous materials

The Flumen River enters the study area at 356 m a.s.l. and leaves it at 328 m after traveling about 6 km with a drop of 28 m in elevation and a general slope of 3%. The land slope is <2% in 52% of the study area and > 10% only in 5% of the area. The mean elevation of the geomorphic units gradually decreases from the platform unit (mean 359 m a.s.l.) to the Flumen terraces unit (mean 337 m a.s.l.). The differences between the median elevations of each of the four geomorphic units are significant and consistent (Figure 3). The interquartile ranges also seem consistent, with the broadest for the river terraces followed by the platforms. The significant differences in elevation between the geomorphic units obtained from LiDAR data reinforce the reliability of these units which were first established by Nogués (2002) using geomorphic criteria.

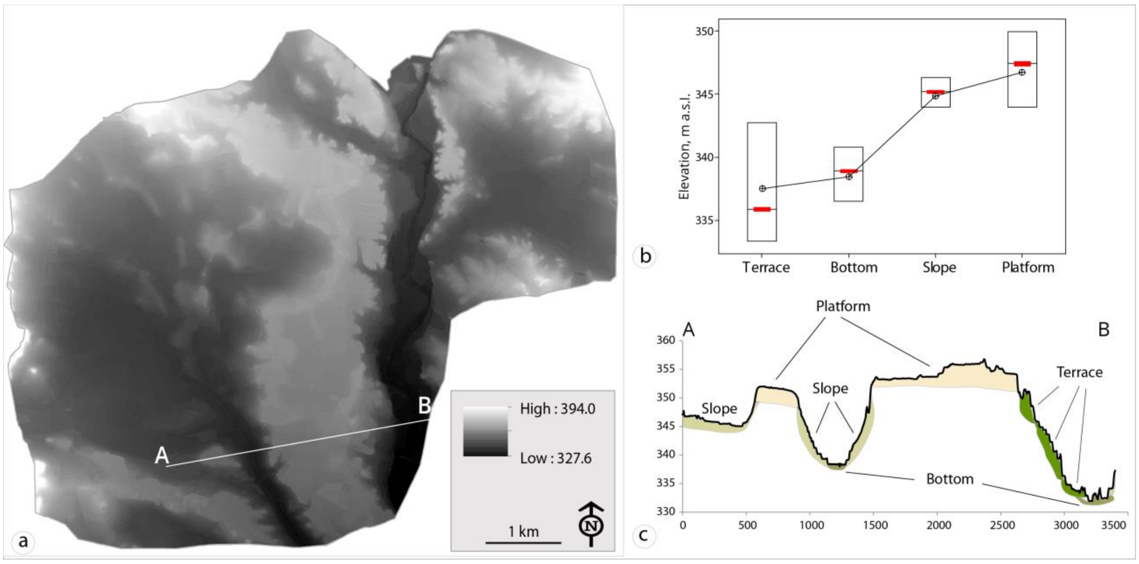

Figure 3. (a) LiDAR-derived DTM of the study area. (b) The elevation of the four geomorphic units, medians and their confidence interval (in red), interquartile range boxes, means and their line connection. (c) A-B cross profile with the main geomorphic units labeled.

4.2. Map units and soil map legend: the Soil Series

As noted by Hartemink (2015) the use of Soil Taxonomy is more frequent in the United States than in Europe. In Spain, the map of Barbués was one of the first published soil maps based on Soil Taxonomy and drawn over an orthophotograph at a scale allowing identification of agricultural plots, with typical size of ~1 ha in the study area. A total of 133 map units were delineated at 1:25,000 scale and constitute the soil map legend (Figure 4). This soil map is considered detailed because it: 1) involves one soil observation per 11 ha; 2) depicts Soil Series that represent the highest precision level in Soil Taxonomy; and 3) establishes consociations and complexes of Series for grouping the different soil taxa identified in the field (van Wambeke & Forbes, 1989). The soil complexes contain two or more dissimilar taxa occurring with a repeating pattern whereas soil consociations are map units dominated by soils of a single soil taxon. Finally, soil taxa were modified with the salinity phases obtained from the soil salinity survey.

The soil map comprises 27 Soil Series (Table 2) belonging to 12 Soil Subgroups and three Soil Orders, Aridisols, Entisols, and Inceptisols, whose surface extents are 8.9%, 63.8%, and 27.3%, respectively. Aridisols include the Subgroups Xeric Haplocalcids and Calcic Petrocalcids. Entisols consist of Haplic Xerarents, Oxyaquic and Typic Xerofluvents, and Lithic, Lithic Xeric, Oxyaquic and Typic Torriorthents. Inceptisols consist of Petrocalcic and Typic Calcixerepts, and Gypsic Haploxerepts. Figure 4 shows the soil map of the two municipalities studied and the legend corresponding to the Soil Series of a sample area.

The resulting soil map is user-oriented in that it summarizes the soil physical and chemical properties that are relevant for agriculture. The definition of map units, based on Soil Series complemented with salinity phases, is focused on the problem of irrigation in salinity prone areas. These units are established in terms of soil depth, drainage, texture and coarse fragments at the surface horizon, soil water retention capacity, and geomorphic unit (Table 3). The soil map represents a landscape model whose units can include more than one soil taxon.

The system of soil classification used illustrates the soil diversity that cannot be represented by the geomorphic mapping alone. Furthermore, as discussed by Brevik et al. (2016), the information from the soil map can be used to address issues beyond agronomic production or to improve the quality of geologic or geomorphic maps that are not available in the area with sufficient or desirable resolution. This usefulness of soil maps to refine or guide geological mapping has been highlighted by Brevik & Miller (2015) in the context of soil mapping in the USA.

In order to extend the soil map with new sheets or to compare the map units from different locations, standardization (Brevik & Arnold, 2015) and correlation of Soil Series are needed. However, the Soil Series established for Barbués have not been submitted to a map correlator because there is no regional soil mapping program. This situation can justify the definition of some Series with exceptionally little extent (≤ 5 ha, Table 2) because our experience in adjacent areas suggests that they might cover much larger areas. To our knowledge, correlation of Soil Series in Spain has been carried out only by IGC (2012) on their soil maps at 1:25,000 scale that also uses Soil Taxonomy as the classification system, and Soil Series as the taxonomic unit.

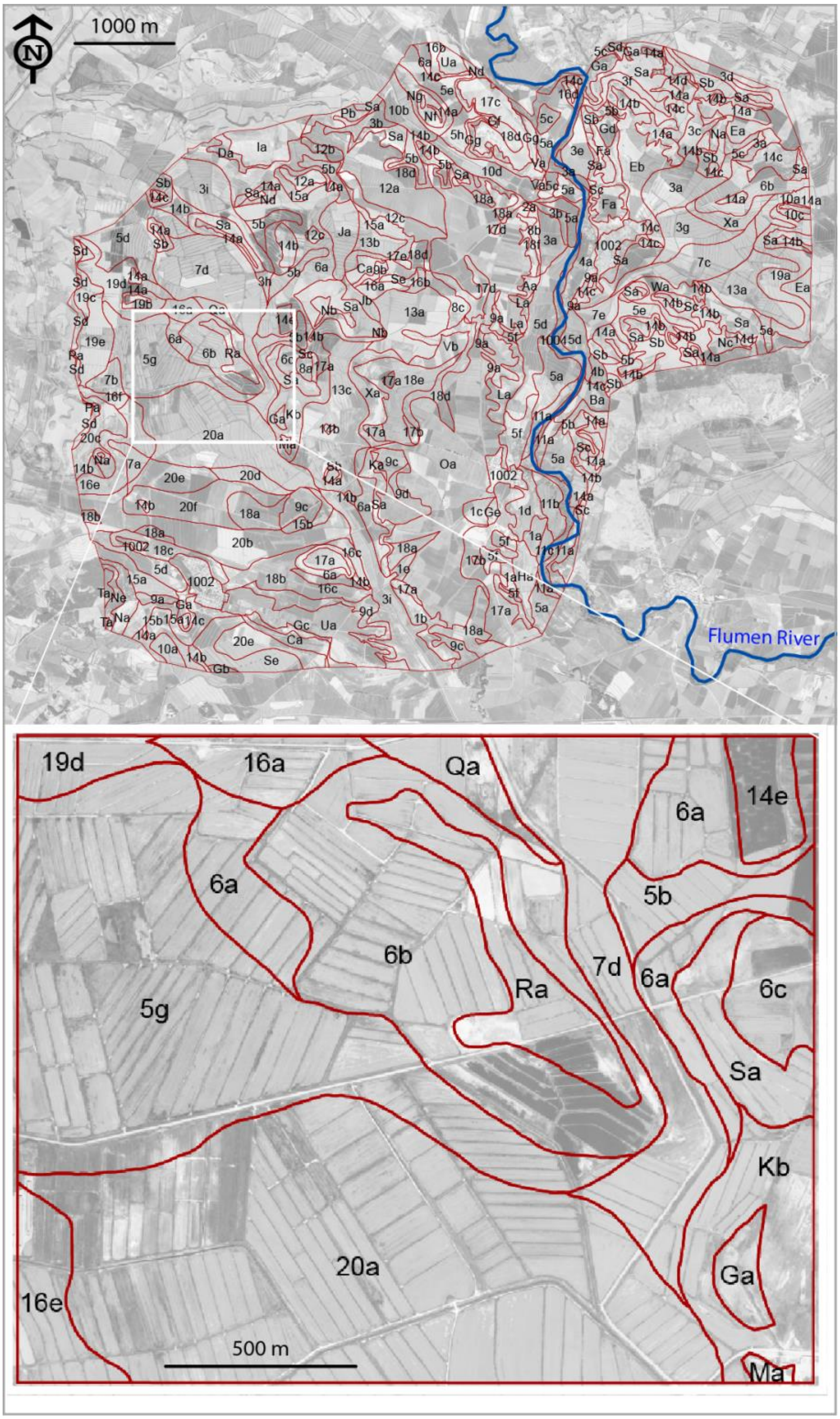

Figure 4. Soil map of Barbués and Torres de Barbués and an enlarged sample area. The scale of the map allows identifying individual plots and the soil attributed to them. The labels in the sample area are explained in Table 3.

Table 2. Soil series in the soil map of Barbués and Torres de Barbués, with their classification, extent, and typic pedon (Nogués, 2002).

Series	Classification following Soil Survey Staff (1999)	Extent (ha)	Typic pedon
Barbués	Coarse-loamy, mixed semiactive, thermic, Typic Calcixerept	5	BA18
Cadillón	Sandy-skeletal, carbonatic, thermic, shallow Calcic Petrocalcid	<1	BA03
Callén	Fine-loamy, mixed, semiactive, calcareous, thermic Typic Xerofluvent	208	BA01
Chacilla	Sandy, mixed, thermic Typic Xerofluvent	20	BA17
Cordel	Fine-loamy, mixed, semiactive, calcareous, thermic Typic Xerofluvent	371	BA06
Corraletes	Fine-loamy, mixed, subactive, calcareous, thermic Haplic Xerarent	19	BA10
Escalerón	Coarse-loamy, mixed, subactive, calcareous, thermic Typic Xerorthent	250	BA22
Escubizal	Fine-loamy, mixed, subactive, thermic Typic Calcixerept	5	BA29
Francal	Fine-silty, mixed, subactive, calcareous, thermic Oxyaquic Xerofluvent	137	BA40
Gor	Coarse-loamy, mixed, subactive, thermic Typic Calcixerept	15	BA12
Lacobeta	Loamy-skeletal, mixed, semiactive, thermic Xeric Haplocalcid	55	BA27
Lalera	Coarse-loamy, mixed, active, calcareous, thermic Oxyaquic Xerofluvent	59	BA32
Osplanos	Fine, mixed, subactive, calcareous, thermic Typic Xerofluvent	162	BA39
Molinar	Sandy-skeletal, carbonatic, thermic, Typic Xerofluvent	41	BA16
Montestruc	Loamy-skeletal over clayey, mixed, subactive, thermic Typic Calcixerept	99	BA07
Piarena	Loamy, mixed, semiactive, calcareous, thermic Lithic Xeric Torriorthent	388	BA19
Planteros	Sandy-skeletal, mixed, thermic Petrocalcic Calcixerept	134	BA11
Puyalón	Loamy, mixed, subactive, calcareous, thermic Lithic Xerorthent	12	BA35
Rompida	Fine-silty, mixed, subactive, calcareous, thermic Haplic Xerarent	77	BA09
Salagones	Clayey, mixed, subactive, calcareous, thermic, shallow Oxyaquic Xerorthent	241	BA05
Sangarrén	Fine-loamy, mixed, subactive, thermic Typic Calcixerept	5	BA21
Santana	Fine-loamy, mixed, semiactive, thermic Typic Calcixerept	1	BA31
Torraza	Loamy-skeletal, mixed, active, thermic, shallow Calcic Petrocalcid	136	BA15
Torres	Loamy-skeletal, mixed, semiactive, thermic Typic Calcixerept	332	BA33
Treshuegas	Fine, mixed, subactive, calcareous, thermic Typic Xerorthent	111	BA02
Valdepinillos	Sandy, mixed, thermic Typic Calcixerept	5	BA14
Valfonda	Fine, mixed, subactive, thermic Gypsic Haploxerept	290	BA25

Table 3. Map units (consociations in blue, complexes in red) appearing in the sample area of Figure 4, and main characteristics of the corresponding Soil Series.

Map unit	Series	Depth	Drainage	Texture	Coarse fragments, %	AWHC1.5, mm	Geoforms	Sequence of horizons
5b, 5g	Cordel	Very deep	Good	Medium to moderately fine	No	Very high, 260 mm	Bottoms, gentle slopes (2-5%), and fluvial terraces	Ap Bw1 Bw2
Kb	Corraletes	Deep or moderately deep	Moderately good	Medium or coarse	Very frequent, 16-35%, decreasing with depth	Low, 140 mm	Slopes (6-10%) starting at the platforms topped by coarse sediments	Ap Bwk C (weathered sandstone) R (sandstone)
6a, 6b, 6c, Qa	Escalerón	Moderately deep	Good	Moderately coarse	Few, 1-5%	Low, 100 mm	Gentle slopes (2-5%), and occasionally (6-15%)	Ap Bw R (sandstone)
7d, Ga	Francal	Very deep	Imperfect	Moderately fine	No	Very high, 280 mm	Bottoms with very gentle slope (<2%)	Ap Bw1 Bw2
Ma, Ra	Lacobeta	Moderatey deep	Good	Moderately coarse	Abundant, 36-70%	Very low, 40 mm	Residual platforms with gentle slope (2-5%), topped by shallow deposits of gravels	Ap/ Bk (gravels) R or Cr (sandstone or lutite)
Ga, Kb, Ma, Sa	Piarena	Shallow	Good	Moderately coarse or coarse	Very few, <1%	Very low, 40 mm	Structural platforms with slope from very gentle (<2%) or gentle (2-5%)	Ap R (sandstone)
Qa, Ra, Sa	Salagones	Moderatey deep or shallow	Moderate or imperfect	Moderately fine	No	Low, 70 mm	Slopes from gentle to steep, also on platforms and water divides of gentle slope	Ap Cr (lutite)

Abbreviations. AWHC1.5: available water holding capacity up to 1.5 m.

4.3 Application of Maps for irrigation design

Three maps at 1:25,000 scale display soil properties of interest for improving irrigation in the area: soil salinity, available water holding capacity, and soil texture plus coarse fragments (see Main Map associated with this article). These maps are essential for irrigation design and management. Enhancing decision making is one of the key purposes of soil surveys (Arnold, 2016) and the utility (or success) of a soil map is determined by its final users. Herrero et al. (2007) derived from the soil map a suitability map for 1) standard frequency sprinkling; 2) high-frequency sprinkling; and 3) flood irrigation. This would be the map for decision makers and irrigators concerned by the upgrading of irrigation systems. These maps allow understanding and forecasting the impacts of their decisions. Moreover, the advantage of using Soil Taxonomy is that many data sets and guidelines for analyses and interpretations are of broad use and available to the public on the Internet.

4.3.1. Soil salinity phases

The distribution of saline and non-saline soils corresponds to that of geomorphic units, since the landscape controls the redistribution of salts. For this reason, the salinity survey was limited to the bottoms and slopes (Nogués et al., 2006), where the water seeps causing salinization due to the evaporation in low lying landscape positions. The map of salinity phases includes 494 ha slightly or moderately saline, and 262 ha strongly or very strongly saline. Saline soils are found only in irrigated areas and represent 24% of the two municipalities studied.

4.3.2. Available water holding capacity (AWHC)

The map of AWHC was obtained for a soil depth of 1.5 m for the 27 soil Series (Herrero et al., 2007). The five classes established in the map correspond to AWHC data ranging from very low (<64 mm) to very high (>250 mm) and follow the classes established by Soil

Conservation Service (1983). Sixty-six percent of the area has low (64–107 mm) or very low (< 64 mm) available water retention capacities and mainly corresponds to soils with moderately coarse textures (65% of area with very low AWHC) though low capacities are also found in moderately fine textured soils (51% of area with low AWHC). These soils with low irrigation efficiency (Herrero et al., 2007) correspond to platforms and are suited for changing the irrigation system into sprinkle irrigation. Thirty-thee percent of the study area has high to very high available water retention capacities and these soils also have a high efficiency of flood irrigation. Most of this area has rice cultivation.

4.3.3. Soil texture and coarse fragments in the surface horizon

The distribution of textural classes and coarse fragments controls surface water ponding. Problematic soils have moderately fine-textured surface layers which limit the water flow. In the study area these soils occur on platforms covered with > 5% of coarse fragments and where infiltration velocities are high (Herrero et al., 2007). The surface layer is almost free of coarse fragments (< 5%) in 59% of study area and soils are susceptible to infiltration problems.

5. Conclusions

Soil mapping at detailed scales collects pedological information that requires simplification to be easily understood by stakeholders and ready for application. Our map provides information about soils at a scale useful for irrigation design and management. The derived maps of water holding availability, soil salinity and texture —as the main limitations for the modernization of irrigation in the study area— show the distribution of the target soil features for the design of irrigation upgrading. Soil Taxonomy performed well in gathering soil properties of interest not only from the point of view of genesis and diversity but also for application to agriculture and environment. The map will help to modernize irrigation systems, thus responding to the societal demand for wise water irrigation use under critical conditions driven by aridity and potential salinity. The definition and mapping of Soil Series of Soil Taxonomy, complemented with the delineation of soil salinity phases, meets these requirements.

Software

ArcGIS® v.10.3 was used for spatial analysis of vector covers and raster data. The digital elevation model was processed using ArcGIS as well as Erdas Imagine® 2015. Maps were produced in the ETRS89 reference system and UTM 30 N and edited with Illustrator CS5. Statistical data were processed within StataIC v.12 and Minitab v.15.

Acknowledgements

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Soil mapping for improved irrigation in a salinity prone area, NE Spain

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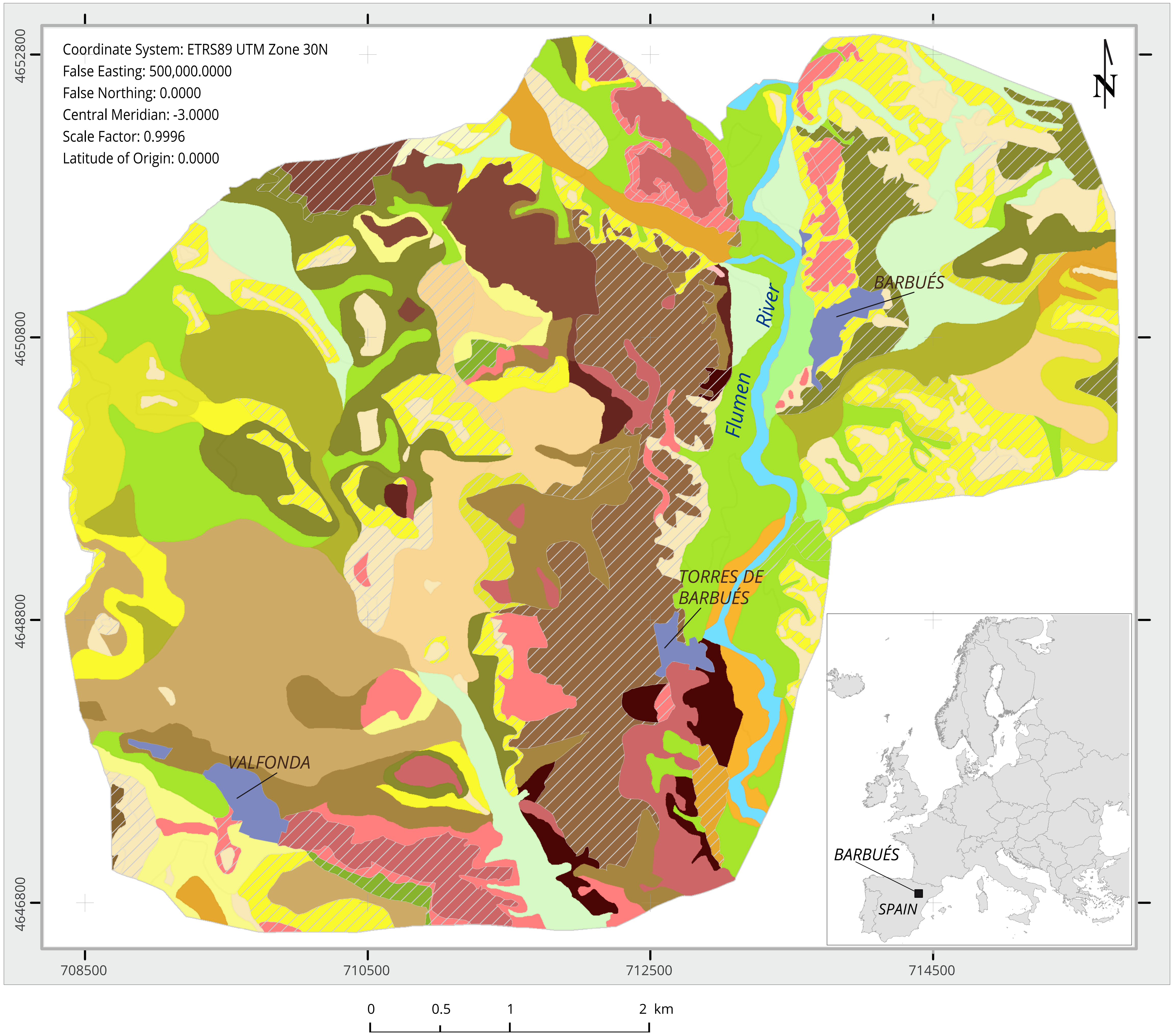


Soil Series

Entisols

- ■ Callén (Fine-loamy, mixed, semiactive, calcareous, thermic Typic Xerofluvent)
- ■ Chacilla (Sandy, mixed, thermic Typic Xerofluvent)
- ■ Cordel (Fine-loamy, mixed, semiactive, calcareous, thermic Typic Xerofluvent)
- ■ Corraletes (Fine-loamy, mixed, subactive, calcareous, thermic Haplic Xerarent)
- ■ Escalerón (Coarse-loamy, mixed, subactive, calcareous, thermic Typic Xerorthent)
- ■ Francal (Fine-silty, mixed, subactive, calcareous, thermic Oxyaquic Xerofluvent)
- ■ Lalera (Coarse-loamy, mixed, active, calcareous, thermic Oxyaquic Xerofluvent)
- ■ Molinar (Sandy-skeletal, carbonatic, thermic, Typic Xerofluvent)
- ■ Osplanos (Fine, mixed, subactive, calcareous, thermic Typic Xerofluvent)
- ■ Piarena (Loamy, mixed, semiactive, calcareous, thermic Lithic Xeric Torriorthent)
- ■ Puyalón (Loamy, mixed, subactive, calcareous, thermic Lithic Xerorthent)
- ■ Rompida (Fine-silty, mixed, subactive, calcareous, thermic Haplic Xerarent)
- ■ Salagones (Clayey, mixed, subactive, calcareous, thermic, shallow Oxyaquic Xerorthent)
- ■ Treshuegas (Fine, mixed, subactive, calcareous, thermic Typic Xerorthent)

Inceptisols

- ■ Barbués (Coarse-loamy, mixed semiactive, thermic Typic Calcixerept)
- ■ Gor (Coarse-loamy, mixed, subactive, thermic Typic Calcixerept)
- ■ Montestruc (Loamy-skeletal over clayey, mixed, subactive, thermic Typic Calcixerept)
- ■ Planteros (Sandy-skeletal, mixed, thermic Petrocalcic Calcixerept)
- ■ Santana (Fine-loamy, mixed, semiactive, thermic Typic Calcixerept)
- ■ Torres (Loamy-skeletal, mixed, semiactive, thermic Typic Calcixerept)
- ■ Valfonda (Fine, mixed, subactive, thermic Gypsic Haploxerept)

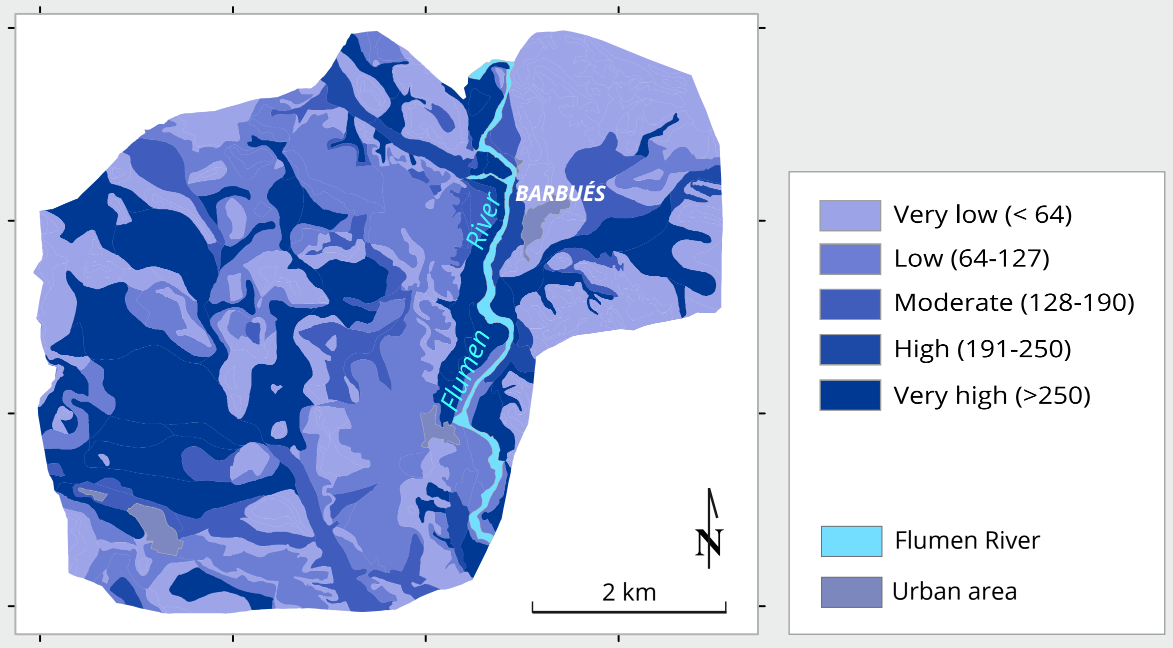
Aridisols

- ■ Cadillón (Sandy-skeletal, carbonatic, thermic, shallow Calcic Petrocalcid)
- ■ Lacobeta (Loamy-skeletal, mixed, semiactive, thermic Xeric Haplocalcid)
- ■ Torraza (Loamy-skeletal, mixed, active, thermic, shallow Calcic Petrocalcid)

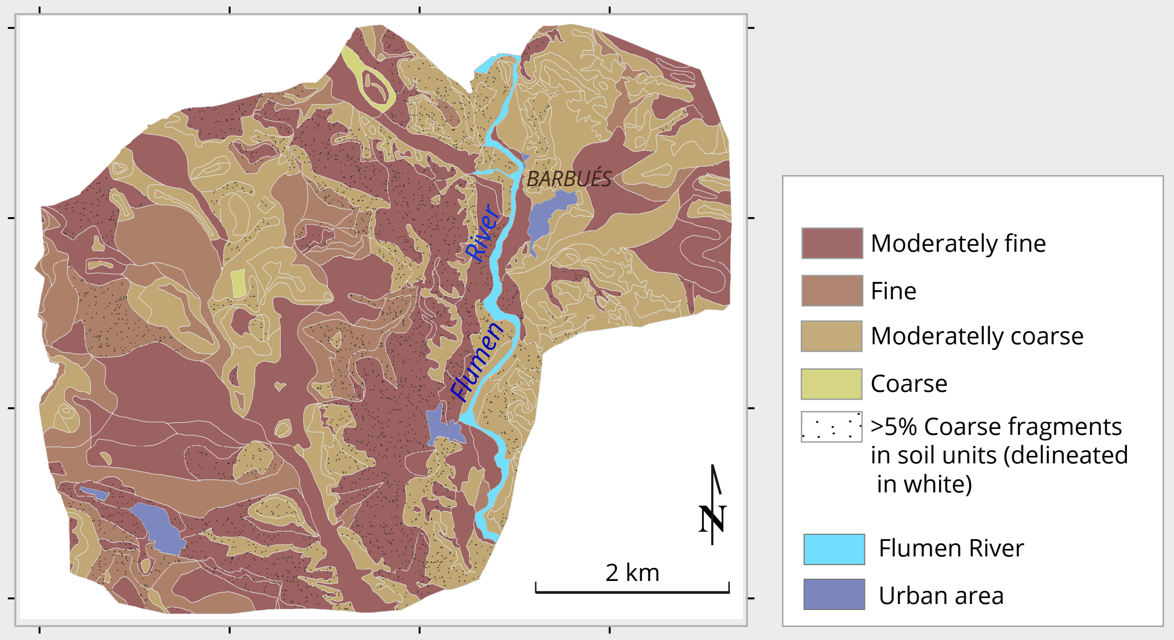
- ▨ Complexes

- ■ Flumen River
- ■ Urban area

Available water holding capacity (mm)



Texture and coarse fragments



Salinity (dS m^{-1} at 25ºC)