Characterization and Soil Mapping of the Caia Irrigation Perimeter

J. Nunes, L. Loures, A. Loures, A. Piñeiro, A. Albarran

Abstract— The Caia Irrigation Perimeter is an irrigation infrastructure that had its start of operations in 1968. The soil map of this region, made before the Irrigation Perimeter construction (1961), uses a 1:50 000 scale and the Portuguese soil classification system, which, though remarkably elaborate, did not achieve the desirable wide world dissemination. So, it seemed two us imperative that the classification of these soils were redone, updated, using a larger scale and therefore more suited to the characterization of a relatively small sized zones, where intensive agricultural practices take place, and using a system of soil classification universally accepted, the system recommended by the FAO World Reference Base for Soil Resources [1]. For this purpose, we begun by gathering the geological characterization of the study area and information about the topography of this region. Based on the overlap of this two kinds of information, we identify areas that matched a particular geology and topography (main differentiating aspects of the soil units on this region), allowing the establishment of a pre-map of soil resources. Based on this pre-map, we define a set of detailed itineraries in the field, evenly distributed, collecting several soil samples in each of the units mapped. In those distinct soil units, we opened several soil profiles, from which we select 26 to present here, the ones characterize the diversity existing in the matter of soil type and in the matter of soil properties.

Based on the work of verification, correction and reinterpretation of the preliminary soil map, we reached the soil map of the Caia Irrigation Perimeter which is characterized by an enormous heterogeneity, typical from Mediterranean soils, containing 23 distinct cartographic units, being the most representative the Distric Fluvisols with inclusions of Luvisols Distric occupying 29,9% of the total study area and Calcisols Luvic with inclusions of Luvisols endoleptic with 11,9% of the total area.

Keywords — Caia Irrigation Perimeter, Soil, Soil classification, WRBSR.

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I. Introduction

The knowledge of the soil resource is of huge importance in any agricultural system [2]. Based on this knowledge we are able to analyze the presence of water, the possibility to practice irrigation or, on the contrary, if given the lack of fitness for more intensive cultural system and, potentially more productive, one should opt for maintaining a rainfed agricultural system. Equally important is the appropriate knowledge on the soil as a way to minimize the process of degradation of this unpaired resource, increasing the sustainability of these man made ecosystems and thus contributing to a more consistent agricultural activity with the current requirements considering environmental protection issues [3, 4].

According to Alexandre & Afonso [5], the soil Charter of Portugal, developed at the scale of 1:50.000 though sufficiently wide to regional planning land use, is insufficient for management at the agricultural production exploitation scale. In fact, this is very clearly the Caia irrigation perimeter. This region, with an area of 7240ha of irrigated land, characterized by a huge diversity of soils, which does not appear mapped with enough detail when using the soil charter of Portugal at the scale of 1:50 000. In addition to what have just been said, the fact that during the 47 years of operation of this perimeter many soils have been altered by human intervention, considering the necessary soil displacement and leveling, which besides increasing irrigation efficiency contributed to change the soil characterization made in the early 60's.

Given the above, conducting a detailed study of these soils, considering a deep analytical characterization of the different soil units, constitutes an indispensable and valuable output. This task become even particularly more important at this stage in the Caia Irrigation Perimeter experiencing a period of strong cultural reconversion, moving from traditional productions as is the case of the tomato and maize to super-intensive olive grove with all changes to the cultural system resulting therefrom.

Finally it is important to point out that the existing soil classification for this area uses the nomenclature inherent in the classification scheme of Portuguese soils, which is used almost exclusively at the national level disabling the possibility to assess it internationally giving a clear idea of the type or types of soil present in this region. Also for this reason it was important to redo the soil classification of the Caia

Irrigation Perimeter , using for this purpose an internationally accepted classification system and widespread as is the case of FAO system (Food and Agriculture Organization) [1, 6 and 7].

II. Material and Methods

2.1 Brief characterization of the study ara

The study area is located within the administrative townships of Elvas and Campo Maior, at the confluence of the Rivers Caia and Guadiana, near the Portuguese-Spanish border (Figure 1). The geology of this area consists essentially of Cambrian and Silurian formations, with some small eruptive zones associated with hyper-alkaline and alkaline rocks. The average annual rainfall is approximately 483 mm, most of which coincides with the coolest temperatures from October to March. The maximum average monthly temperature corresponds to July with 24.7°C and the minimum to January with 8.8°C. The Mediterranean region is characterized by its hot dry summers (with direct influence in soils properties) and cool wet winters. The most important crops are: maize (*Zea mays*) for feed-grain production with almost half of the cultivated area (49%), wheat (*Triticum aestivum*) (17%), sunflower (*Helianthus annuus*) (7%), tomato (*Lycopersicum esculento*) (6%), and olive (*Olea europea*) (4%).

Regarding slope the study area is characterized essentially be flat or very gentle slopes. 80.7% of the study area has slopes below 3%, 16.7 % have slopes between 3 and 5%, while only 2.6% of the study area has slopes greater than 5% and generally these areas are not used for irrigated productions.

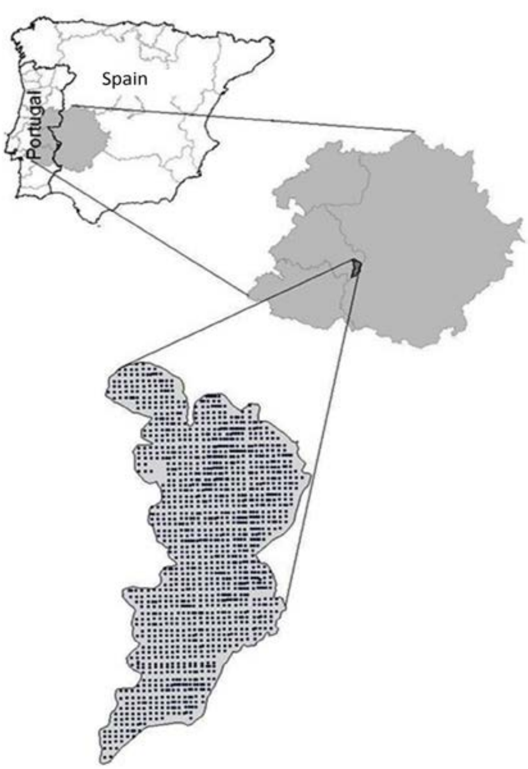

Figure 1 – Localization of the study area.

Regarding soil type (Portuguese classification): in the agricultural area covered by the Caia perimeter the predominant soil types are Mediterranean soils from hydromorphic sandstones or conglomerates clay (Pag) occupying 36.1% of the total area, followed by Mediterranean soils of marl or marly limestones (Pac) with 10.8 % of the total area. To these soil units, considered as the most representative, there are more than 10 other types of different soils, whose area is less than 4% of the total area of the perimeter.

2.2 Used method towards the definitions of soil units

The methodology followed in the classification and soil mapping can be subdivided into three major items:

- Office work
- Field work
- Lab work

Regarding office work as a starting point for the development of soil mapping of the study area, first a set of data was compiled, considering maps and other studies of the factors forming soil in the area, including geology [8], climate, topography and vegetation. The topographic data was obtained for analysis on-site, using a precision GPS (Global Position System) indicating altitude, which was then inserted in a GIS software to generate the respective map (Figure 2).

This information allowed us to establish the routes and to understand the potential of the soil type in the area under study, providing the basis for the development of the required mapping. For the classification of different soil types we used the methodology recommended for WRBSR [9].

Regarding field work a first field trip was held to establish contact with the study area and in order to plot on the map its limits. Based on the obtained information and on the data previously obtained in office, a first preliminary map of the Caia Irrigation Perimeter was drawn.

In order to test the adjustment of this map to the geological reality, considering soils and geomorphology already mapped, a number of routes in the field, uniformly distributed, was planned up, collecting samples in the different units, in order to establish both the type and variability of existing soils in each of the previously identified units.

Based on the previously described work and evidences, corrections and reinterpretations of the preliminary soil map were performed, in order to enable the selections of the soils that, according to our perception, best represented soil diversity considering both a typological point of view and soil properties.

Considering the characterization of the different soil types, we proceeded to the survey of 26 soil profiles and their description, carried out according to the FAO Profile Description Guide [9] and to the Munsell Color Chart [10]. Samples of each of the horizons of different profiles were collected and, once properly packaged, labeled, cataloged and then transported to the laboratory.

Regarding lab work all the samples were air dried. After this drying process part of the sample was used in the determination of rough elements, while the remaining fraction of the sample was sieved, through a stainless steel sieve with a 2mm mesh.

The performed analyzes were: particle size analysis - conducted by the method of Robinson pipette [11]; organic carbon – considering the wet oxidation with potassium dichromate, followed by quantitative determination by titration with ferrous sulphate [12]; pH - potentiometry a soil/water mixture (1:5 v/v); electrical conductivity - dosed with a conductivity in an aqueous extract (1:5 v/v) under Rhoades [13]; Total nitrogen - according to the Kjeldahl method [14]; Phosphorus and potassium "assimilated" - according to Egner - Riehm method [15]; calcium and magnesium - extracted with ammonium acetate buffered to pH 7 [11]; exchange of bases and acidity - Extraction with a barium chloride solution buffered at pH 8.2 triethanolamine - Mehlich method [16]; Extracting microelements (Cd, Cr , Cu, Fe , Mn, Ni , Pb, Zn) – Extracted with a solution of ammonium acetate , acetic acid and EDTA - Lakanen and Ervio method [17]; Chlorides - extraction with water and assay by titration with silver nitrate - Mohr's method [11] and carbonates - dosed by a volumetric calcimeter Bernard [18].

III. Results and Discussion

As shown in Table 1, the area of the Caia Irrigation Perimeter has a significant diversity of soils. The area comprises mainly four soil groups, including Fluvisols, Luvisols, Calcisols and Cambisols, totaling 98.8 % of the area under study. Of these, the first 2 groups comprise 74.6 % of the study area, Cambisols are the group with lower expression, representing only 5.4 % of the area. There are other groups of soils whose representation is very reduced, in particular Leptosols with 0.1 % of the total area and Regosols with 1.1 % of the total area.

Table 1 – Representation of the reference units according to WRBSR (2006) at the Caia Irrigation Perimeter.

Soil group	Area (ha)	Area %	Accumulated %
Leptosols	9	0,1	0,1
Regosols	150	1,2	1,3
Fluvisols	5640	44,9	46,2
Cambisols	693	5,5	51,7
Luvisols	3725	29,6	81,3
Calcisols	2342	18,7	100
TOTAL	**12549**	**100**	

Considering the taxonomic levels 23 different soil units were identified (Table 2 and Figure 2), the Distric Fluvisols with Distric Luvisols inclusions was the most represented soil unit occupying 29.9% of the total study area.

The soils of the region, of which only 51.4 % are regularly utilized in irrigation (the remaining area is rainfed) are characterized by having good drainage conditions (90.7 % soil good drainage) present a medium to high depth (66.1 % of soils have a useable depth greater than 1 m and 27.7 % have a useful depth of between 50 and 100 cm) and low stony (92.3% of stony soils have a lower 15 %).

From a chemical point of view these soils are mostly neutral to slightly alkaline (38.6% of the study area presents a pH between 6.0 and 7.0 and 38.3 % have pH between 7.0 and 8.0), with low electrical conductivity (EC), probably the result of good quality of water used in irrigation (90.2 % of the soils of this region have EC less than 0.25 dS m^{-1}), low in organic matter (66.2 % of the soils have an organic matter content of less than 1.5% and only 6.9 % had more than 2.0 % of this important soil component), with an average quality at high "assimilable" phosphorous (73,5 % soil this region have more than 100 mg kg^{-1} of P_2O_5) and high to very high "assimilable" potassium (94.4 % of soils have more than 100 mg kg^{-1} K_2O "absorbable" and 50.9 % soils have more than 200 mg kg -1 "assimilable" potassium. These soils are still, on average, with low-quality active limestone (74.8 % of the soils of this region are between 0 and 25% $CaCO_3$) with high-average Cation Exchange Capacity (CEC) (69.5 % of the region's soils have more than 10,0 $cmol_{(+)}$ kg^{-1} CEC, while for 12.2% of the region soils this value exceeds 20.0 $cmol_{(+)}$ kg^{-1}) in which calcium is largely dominant and the percentage of sodium exchange is to over 95% of the land area of less than 5 %.

Table 2 – WRBSR soil representation – soil type abundance at the study area

Cartographic Units	Area (ha)	Area %
Eutric Leptosols with dystric Leptosols inclusions	9	0,1
Distri-epileptic Regosols with dystric Leptossolos inclusions	150	1,1
Dystric Fluvisols with dystric Luvisols inclusions	3747	29,9
Eutric Fluvisols with mollic Fluvisols inclusions	703	5,6
Eutric Fluvisols with cutanic Luvisols inclusions	1190	9,5
Eutri-endoleptic Cambisols with cutanic Luvisols inclusions	458	3,7
Endoleptic Cambisols	18	0,2
Endoleptic Cambisols with eutric Leptosols and dystric Leptosols inclusions	207	1,6
Cutani-endoleptic Luvisols	506	4,0
Cutanic Luvisols	16	0,2
Calcic Luvisols	91	0,7
Calcic Luvisols with luvic Calcisols inclusions	997	8,0
Calcic Luvisols with cutanic Luvisols inclusions	889	7,1

Cutanic Luvisols with cutani-endoleptic Luvisols inclusions	93	0,7
Dystric Luvisols	154	1,2
Cutanic Luvisols with calcic Luvisols inclusions	601	4,8
Endoleptic Luvisols with eutric Leptosols inclusions	150	1,2
Luvisols with calcic Vertisols inclusions	228	1,8
Luvic Calcisols with vertic Calcisols inclusions	440	3,5
Luvic Calcisols with sodi-mollic Cambisols inclusions	158	1,3
Luvic Calcisols with cutani-endoleptic Luvisols inclusions	1497	11,9
Luvic Calcisols with vertic Luvisols inclusions	59	0,4
Vertic Calcisols with calcic Vertisols inclusions	188	1,5
TOTAL	**12549**	**100**

Comparing the types of soil of the study area presented at the Portuguese Soil Map at the scale of 1:50.000 (1961) with the Soil Map obtained in the present work, although the classification system used is different and therefore difficult to compare with any other classification system, it is possible to verify the existence of a substantially larger number of different classes in this study, confirming, as previously reported by Alexander & Afonso (2007), the limitations of the Portuguese Soil Map when one needs to get further information with greater detail than the one which was used in its execution.

IV. Final Remarks

The region under study presents a wide range of soils. The performed analysis enabled the classification of 23 different soil units according to WRBSR (2006) having a number of substantially higher soil units that shown in Portuguese Soil Map. Focusing only on higher taxonomic levels one can see that the dominant soil groups in the region are Fluvisols, occupying 44.9% of the total area, followed by Luvisols with 29.6% of the total area. These two groups of soils together with Calcisols represent more than 90 % (93.2 %) of the soils of the region under study.

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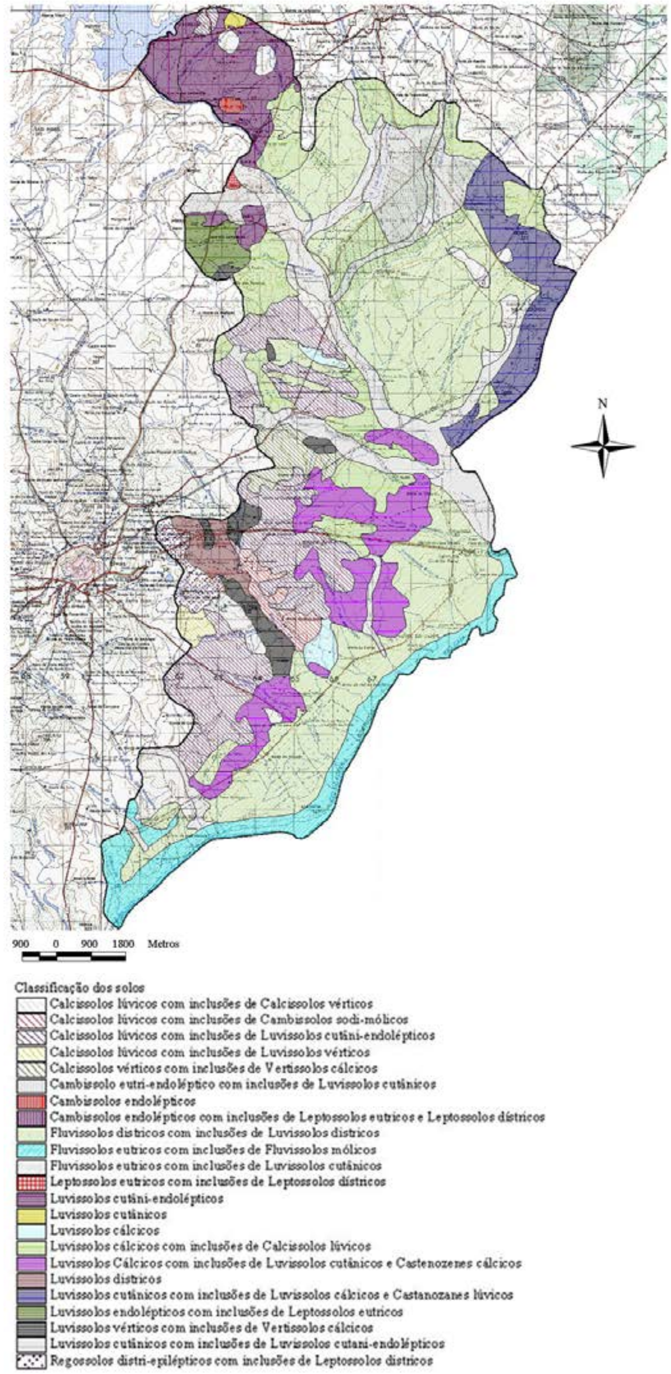

Figure 2 – Carta de Solos do Perímetro de Rega do Caia

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