Brief Characterization And Analysis Of Soils And Climate And An Analysis Of Suitability To Irrigation Of The Portuguese Continental Territory

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Abstract

This paper briefly presents the climatic and soil major characteristics of the Portuguese continental territory, and it's potential for irrigated arable crops.

The analysis was done with the support of a geographic information system, and the maps it produces present the results.

Keywords — *Land Use, Irrigation, Agriculture and Environment, Pictures and Maps.*

I. INTRODUCTION

Knowledge on soil, climate and water resources is indispensable to any form of agricultural planning. In what climate is concerned, we should consider solar radiation, rainfall, temperature, wind, air moisture content and frost incidence as having direct implications on crop growth.

The "climate" of a certain area is defined by the weather conditions predominant in the same area, and, therefore, characterized by the behavior of climatic variables during a given period of time (a period of 30 years is usually considered). The climate of an area limits the types of crops to grow, as well as productivity.

The concept of "climate" can be analyzed at several scales:

- Macro-climate: areas larger than 2000km, determined essentially by latitude and general atmospheric circulation;
- Regional climate: areas ranging from 200 to 2000km inside macro-climatic areas, determined mostly by relief;
- Local climate: small areas inside regional climates, determined by variability in altitude, predominant orientation of mountains and existence/non-existence of forest;
- Micro-climate: modifications in extremely small areas, determined typically by relief and its role in the determination of sun exposure and local air circulation.

In this analysis we will deal with aspects mostly related to regional climate. What interest do we find in its study?

- finding crops and animal races adapted to a particular situation;
- establishment of major cultural options and evaluation of water deficit/surplus, in order to design irrigation or drainage systems;
- planning of farm activities and resource utilization (working days, human resources, machinery, etc.);
- construction planning (roads, buildings, dams and irrigation networks, etc.).

In its simplest definition, a Geographic Information System (GIS) is a software that allows the association of geometric and tabular data. A more comprehensive definition could be "a system that includes people, hardware, software and logic and allows collection, storage, visualization, extraction and analysis of spatial and associated tabular data, relative to things that exist and events that occur on the surface of the earth" [1], [2].

The ancestor of the GIS is, undoubtedly, the classical paper printed map. Although the issue here is not whether printed maps will or will not disappear in professional environments, it is unquestionable that they present many limitations and there are usually strong motivations to evolve to a GIS. These motivations can be classified into three categories: production related, distribution related and utilization related.

At the production level, we could mention economy and security related to acquisition, updating and maintenance. The traditional difficulties associated with the old boards, their enormous volume, problems with deformation, etc., are widely known. One of the advantages of digital technologies is precisely the guaranty of stability of information, as long as the standards for information safety issues are met. However, it's at the level of updating speed that the revolution really happened: any changes to the information stored in a GIS are carried out with awesome simplicity, by no means jeopardizing the work of months or even years as before [3].

At the distribution level, geographic information acquired the advantage common to all digital information: especially with the vulgarization of the internet, it became trivial to distribute maps, whether we mean the personal level, the corporate level or the inter-corporate level, in its simplest form or associated to sophisticated control and management software [4].Because the passage to a physical support is no longer necessary, the problems related to deformation, deterioration and transport also disappeared.

At the level of utilization *sensu strictu*, the GIS provided the average user with an enormously higher capability of interaction with geographic information: with he possibility of arranging the information into several layers, according to their nature, intra and inter-layer processing, and the possibility of programming any logic with access to both information and procedures, it becomes possible to respond to virtually any formal problem, extending it from a mere displayer and producer of maps into comprehensive instruments of analysis, calculation, planning and decision support. Their analytical capability is, according to several authors, their greatest asset [5]-[9].

In conclusion, we could add that with a SIG, in a certain perspective, disappears the classic path *production-distribution-utilization* of geographic information, as the very concept of utilization implies the concepts of production and distribution. Suddenly, any single user becomes the manager of his own information, able to produce his own maps through his own logic.

This paper is an example of how this "mental map" can be used in order to discuss and analyze, at a macro level, the potential of the physical environment for irrigated crops.

II. CLIMATE

The general traits of the portuguese climate can be defined through the variations observed in the following variables: solar radiation, temperature, rainfall, evapo-transpiration and frost-free period (Fig. 1).

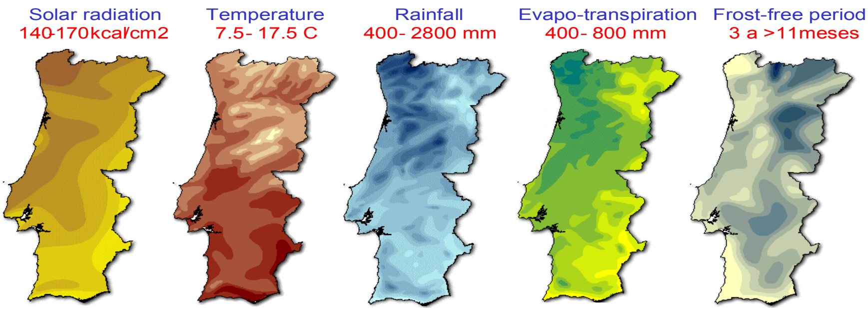

Fig. 1: Variation in solar radiation, temperature, rainfall, evapo-transpiration and frost-free period of Continental Portugal territory (adapted from the "Atlas do Ambiente", Portugal)

Variability is the result of 3 major sources of climatic influence upon the territory: Atlantic, Continental and Mediterranean, which interact with relief (Fig. 2)

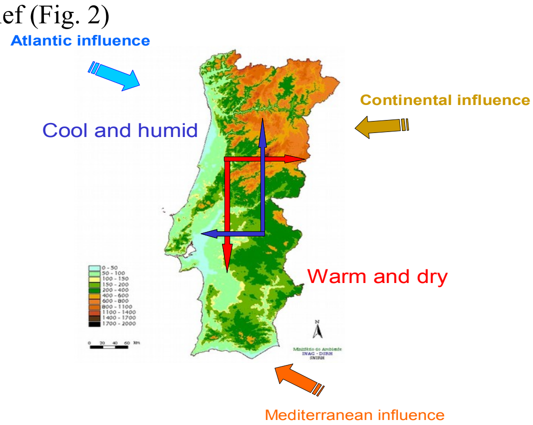

Fig. 2: Major sources of climatic influence upon the of Continental Portugal territory and interaction with altitude

A. Climatic classification

Their purpose is to identify climatic units, based on the factors with greater impact on the earth's surface: rain and temperature. These classification keys are used usually in large scales, at national, continental or global scale, in order to define main climatic types and sub-types (Fig. 3 and 4)

a) Classification based on the average yearly temperature

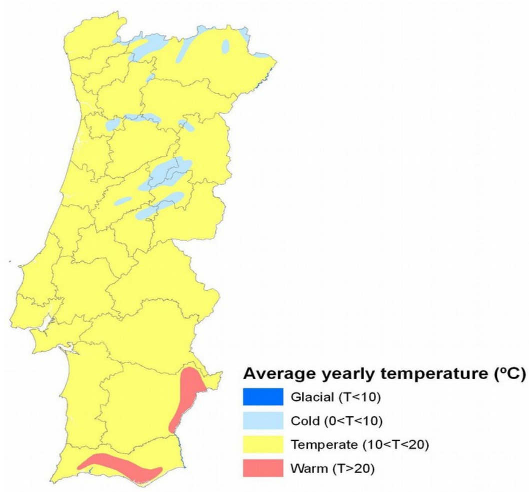

Fig. 3: Classification of the of Continental Portugal territory based on the average yearly temperature

b) Classification based on the average yearly rainfall

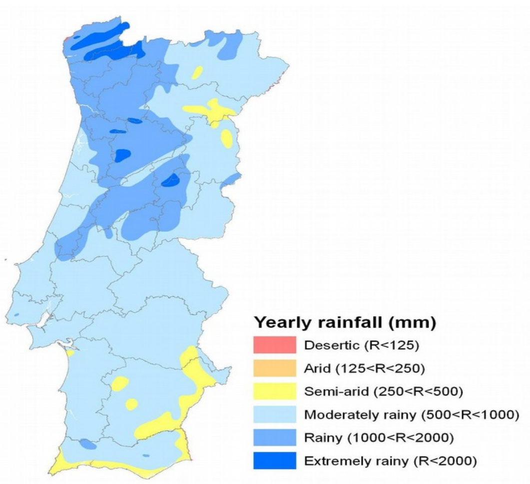

Fig. 4: Classification of the of Continental Portugal territory based on the average yearly rainfall

c) Thornthwaite climate classification

The Thornthwaite climate classification is based on rainfall and evapotranspiration. Whereas the use of evapotranspiration is very useful at continental level, it produces little differentiation at the scale of a small country like Portugal. In this classification key, climate is defined with one character, from 'A' to 'E', and several sub-indexes, of which we will consider the first.

Humidity index

The maximum soil water content (S) considered is 100 mm; R stands for rainfall.

If $R_i + S_{i-1} > ETP_i$, then ETR = ETP, or $ETR_i = R_i + S_{i-1}$

There is a deficit of water (D) when ETR < ETP: $D_i = ETP_i - ETR_i$

There is an excess of water (E) when $S_{i-1} + R_i < 100$: $S_i = (S_{i-1} + R_i) - (ETP_i + 100)$

The humidity index is calculated through $I_h = I_e - 0.6\ I_d$, where $I_d = (D / ETP) \times 100$ and $Ie = (S / ETP) \times 100$

Table I – Humidity index Thornthwaite climate classification

Ih	Climatic type	Designation
Ih ≥ 100	Super-humid	A
80≤ Ih<100		B4
60≤ Ih<80	Humid	B3
40≤ Ih<60		B2
20≤ Ih<40		B1
0≤ Ih<20	Sub-humid	C2
-20≤ Ih<0	Dry - sub-humid	C1
-40≤ Ih<-20	Semi-arid	D
Ih<-40	Arid	E

If we apply this criterion to Portugal, the result is as follows (Fig. 5): humid and super-humid areas in the northwest, and a small area in the southwest; expressive arid areas in the northeast and the south in general, especially the southeast; transitional sub-humid or dry-sub-humid areas in the remaining continental surface.

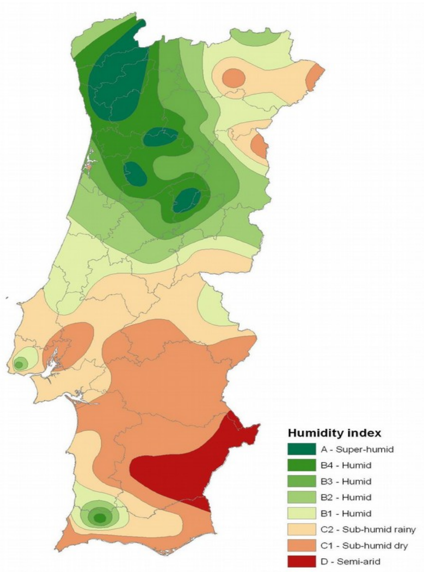

Fig. 5: Thornthwaite humidity index of Continental Portugal

Thermal efficiency

According to the Thornthwaite method, potential evapotranspiration (ETP) is a measure of the thermal efficiency. Therefore, the yearly ETP can be used as such measure for a given climate (Table II and Fig. 6).

Table II – Thermal efficiency Thornthwaite climate classification

ETP	Climatic type	Designation
ETP ≥ 114.0	Megathermic	A'
99.7 ≤ ETP < 114.0		B'4
85.5 ≤ ETP < 99.7	Mesothermic	B'3
71.2 ≤ ETP < 85.5		B'2
57.0 ≤ ETP < 71.2		B'1
42.7 ≤ ETP < 57.0	Microthermic	C'2
28.5 ≤ ETP < 42.7		C'1
14.2 ≤ ETP < 28.5	Tundra	D'
ETP < 14.2	Glacial	E'

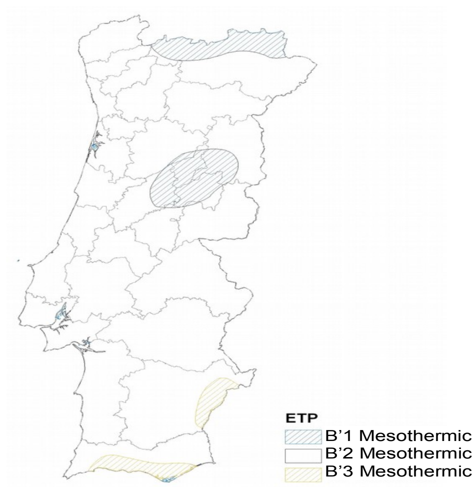

Fig. 6: Thornthwaite thermal efficiency of Continental Portugal

Combining these two indexes, we obtain the following map with the Thornthwaite classification (Fig.7).

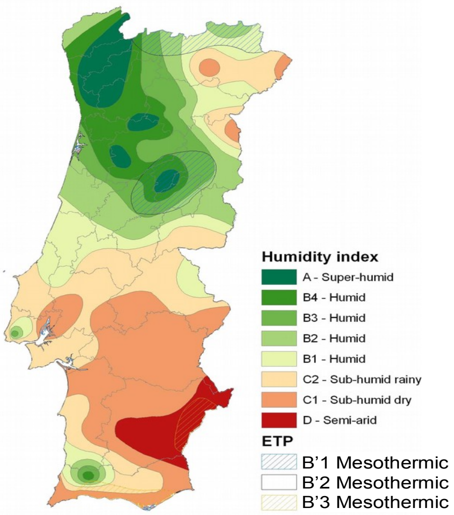

Fig. 7: Thornthwaite classification of Continental Portugal

d) Papadakis climate classification

This is an agro-climatic classification that considers the sensitivity of plants to temperature. The main index refers to both the types of summer and winter (Tables III and IV).

Table III – Papadakis classification of winter types

Equatorial	average temperature of coldest month > 10ºC; average temperatures of cold and warm seasons differ less than 2-3ºC
Tropical	absence of frost; average temperature of coldest month < 18ºC
Citric	moderate frost occurrence; average temperature of coldest month > 8ºC
Oat	average minimum temperatures of coldest month from -2.5ºC to 10ºC
European vine	average minimum temperatures of coldest month from -10ºC to -2.5ºC
Wheat	average minimum temperatures of coldest month from -25ºC to -10ºC

Table IV – Papadakis classification of summer types

Cotton	frost-free period ≥ 4 ½ months; average maximum temperature > 25ºC period ≥ 4 months; maximum temperature > 33.5ºC
Coffee 'arabica'	frost-free period ≥ 4 ½ months; average maximum temperature > 21ºC period ≥ 4 months; maximum temperature < 33.5ºC
Maize	frost-free period ≥ 4 ½ months; average maximum temperature > 21ºC period ≥ 6 months
Spring wheat	frost-free period ≥ 4 ½ months; average maximum temperature from 17ºC to 21ºC period > 4 months
Rice	frost-free period ≥ 3 ½ months; average maximum temperature > 21ºC period > 6 months; average temperature of warmest month > 25ºC

We find (Fig. 8) two main winter type zones: a zone that includes the coast, the territory south of the Tagus River, and the interior south of Beira Baixa, classified as "winter *Citrus*"; a second zone that covers the whole area of influence (towards the interior) of the mountainous massif of the centre of the country, from the mountain range of the Açor, to the south, to the mountain range of the Peneda, to north, including the mountain ranges of the Estrela, Caramulo, Freita, Arada, Montemuro, Cabreira and Gerês classified as "winter *Avena*".

In the summer classification we find a more detailed differentiation. The same area in the south of Portugal, that corresponds, in general terms, to the Alentejo region, southernmost Beira Baixa, a small part of the Estremadura and the Ribatejo, is classified as "summer *Gossypium"*. The exceptions are a narrow coastal belt, classified as "*Zea"*, and part of the Algarve - "Oryza". The coastal half of the Oeste region and mountain range of "Sintra" are classified as "*Triticum*", the coast north of the Mondego River in "*Zea"*. In the centre of the country we find one strong line dividing the coast and the interior. The coast is classified in "*Oryza*", a transition between the "*Gossypium"*, to the south, and the "*Zea"*, to the north. In the interior, in the area of influence of the central massif, the temperatures are sufficient only for a classification in "*Triticum"*.

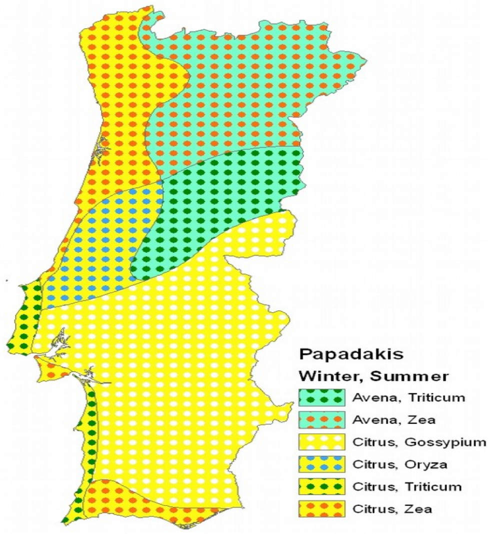

Fig. 8: Papadakis classification of Continental Portugal

e) Köppen climatic classification

The climatic classification of Köppen distinguishes five principal groups of climates, corresponding to five groups of vegetation (Tables V and VI).

Table V – Köppen principal groups of climates

A - Tropical	Absence of cold season
B - Dry	ETP largely surpasses rainfall (inexistence of surface water)
C - Temperate	Mesotermic climates in intermediate latitudes, mild winters
D - Cold or Continental	Microtermic climates, cold winters
E - Polar	Absence of warm season

Classification as "temperate climate" (C) requires at least one month below 18ºC, but average temperatures below -3ºC are not allowed. The following subtypes are considered:

Table VI – Köppen subtypes of climates

Cw - High altitude	High altitude tropical climates, where temperature is reduced by altitude
Cf - Maritime	Even distribution of yearly rainfall
Cs - Mediterranean	Dry summer

The characteristics of Mediterranean climates are easy to enumerate, in general terms: temperate, intermediate latitudes; warm and dry summer; rainfall concentrated in the cold season; mild winter; inter-annual rainfall irregularity, with occurrence of sequences of several dry or rainy years. They are very difficult to characterize in quantitative terms, however. According to the Köppen classification, the Mediterranean climate (Cs) is defined by the following rules:

- Temperature: at least one month with an average temperature below 18ºC; every month must have an average temperature above - 3ºC;
- Rainfall: driest month with less than 1/3 of the wettest; driest month with less than 30mm.

Within the Mediterranean climate, there are two subtypes, referred to different types of summer:

- Hot summer (Csa) - warmest month above 22ºC;
- Cool summer (Csb) - warmest month below 22ºC.

According to the Köppen classification, the data used in this study, and the scale considered, the Portuguese territory is divided as follows, in broad terms:

- Csa (hot summer): Alentejo, southern Beira Baixa, interior Beira Alta and southeastern half of Trás-os-Montes;
- Csb (cool summer): the coastline, the mountainous areas of the Center and North, the north of Trás-os-Montes.

There are also occurrences of Cfb (maritime) in the interior of Minho (mountain ranges of Peneda, Gerês, Cabreira, Barroso e Larouco), and also in Montemuro. The Bsh (semi-arid) also appears in the Algarve and the Guadiana basin (Fig. 9)

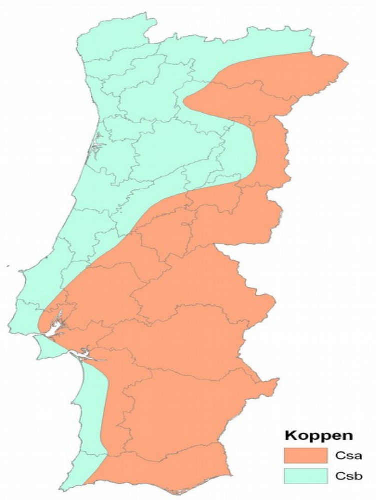

Fig. 9: Köppen's climate classification of Continental Portugal

Considering these results, it is possible to establish the major advantages and disadvantages of the Portuguese climate in what agriculture is concerned.

Major disadvantages:

a) Lack of rain in the summer and part of the spring. Especially in the south, where rainfall is insufficient and irregular. This has a strong effect on non-irrigated crops, namely on the maturation phase of winter crops. This is not a problem with irrigated crops, but it still increases production cost. Random rain at the end of spring, especially when close to harvest, may also destroy part of the product.

b) Rainfall concentrated in the cold season (November to March). Short days and low temperature lead to reduced demand of water, leading to a poor use of this abundance of water and a frequent excessive accumulation, especially in soils with poor drainage (very frequent in Portugal), therefore harming the normal development of plants.

c) Annual and inter-annual irregularity of rainfall and temperature. This produces an increased difficulty in predicting growth and operations on the soil, date of seeding and harvest, instability of production and, many times, poor harvest.

Major advantages:

a) High annual average temperature and high radiation levels. The combination of these two elements allows extended production cycles with high availability of energy, potential for a high productivity and adequate maturation of a wide range of crops (annual crops, vine, fruit, vegetables).Products are, in general, of very high quality, one of the reasons for the present phenomenon of expansion of irrigated areas in Portugal.

b) Absence of rainfall associated with high temperature. Although this may sound like a contradiction with what was said before, it is true that this creates ideal conditions for harvesting and reduces the cost of artificial drying of grains, for instance.

c) Mild winter with sufficient radiation for some crops. Winter temperatures adequate to horticulture and flower production in open-air (coastal areas) or in greenhouses (interior areas), allowing extra-early production cycles.

In theory, the agricultural potential of a given place is a function of:

a) Climate. It affects the growing period (minimum and maximum temperatures and frost-free period), total radiation during that period, and the balance of rainfall and potential evapotranspiration;

b) Soil. Apart from nutritional aspects, which can be overcome to a certain extent by fertilization, it affects rooting and the flowing of water, thus attenuating or aggravating the excess or lack of water;

c) Plant. Through its better or worse adaptation to a particular environmental context, expresses a fraction of its genetic potential.

It's interesting to evaluate the potential gain of overcoming the water deficit, through irrigation [10]. Considering there is a direct proportionality (Ky) between the water deficit (1-Etr/Etp) and the deficit of potential productivity (1-Ya/Ym), we can estimate (in percentage) the average gain of the introduction of irrigation. Based on this reasoning, the maps of Etr, Etp and Water deficit (%) were produced (Fig. 10 and 11).

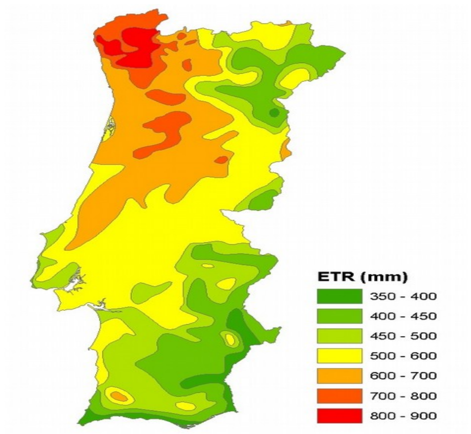

Fig. 10: ETR of Continental Portugal territory

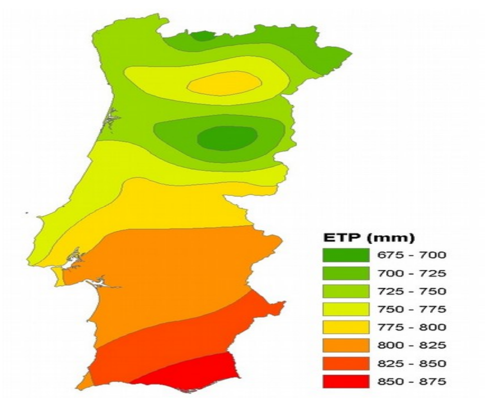

Fig. 11: ETP of Continental Portugal territory

According to this reasoning, and considering that Ky takes a value of 1 (in reality, Ky is >1 for crops more sensitive to stress, like maize, and <1 for crops like sorgo), we can point that all the south and northeast territory of the country presents a higher capacity of response to the introduction of irrigation (Fig. 12). In these territories, the estimated increase in profit could be as high as 30%. If we think, for example, of crops like wheat or Autumn-Winter beetroot, considering maximum productivities of 4 and 80 tons, respectively, we will be able to infer that the profit will increase of 1,2t and 24t, respectively.

One should point, however, that the underlying reasoning to this analysis is simplistic, given the fact that the water deficit was not estimated for the specific growth period, the assumption of a usable water capacity of 100 mm and the Ky being equal to 1: all this forces us to be cautious regarding any possible conclusions.

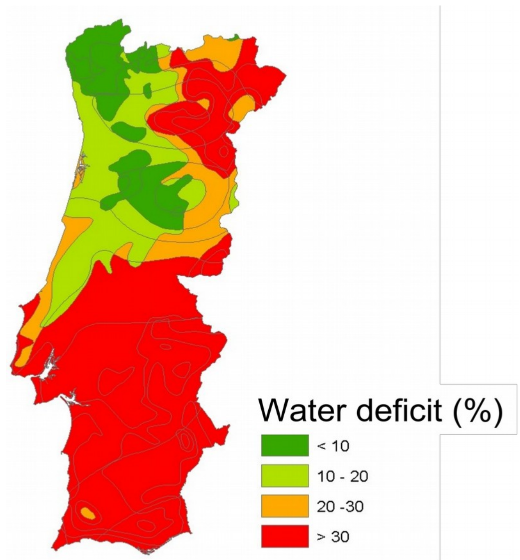

Fig. 12: Water deficit of Continental Portugal territory

III. SOIL

The following image shows the distribution of the main soil types in Continental Portugal (Fig. 13).

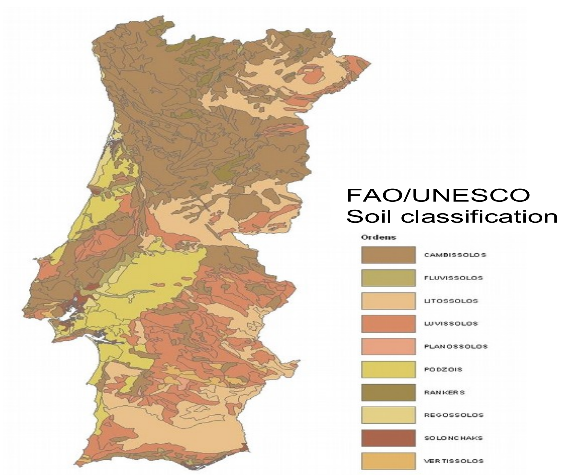

Fig. 13: Soils of Continental Portugal

Table VII shows us the absolute and relative importance of each soil type in Continental Portugal.

Table VII – The importance of each soil type in Continental Portugal

Soil type	Area (ha)	%
CAMBISOLS	3.668.681,2	41,45
FLUVISOLS	104.185,3	1,18
LITHOSOLS	1.871.834,0	21,15
LUVISOLS	1.765.274,1	19,94
PLANOSOLS	18.933,2	0,21
PODZOLS	944.568,1	10,67
RANKERS	168.892,1	1,91
REGOSOLS	120.616,4	1,36
SOLONCHAKS	83.957,1	0,95
VERTISOLS	104.192,1	1,18
Total	8.851.133,6	100,0

The predominant soils are clearly the Cambisoils, with more than 40% of the total area, followed by Lithosoils and Luvisoils, each with approximately 20%. If we add the Podzols, we get roughly 93% of the total area.

The main physical and chemical characteristics are presented in Table VIII. We draw the attention of the reader to the fact that these are based on a selection of actual readings performed on soils in Portugal, assumed representative of each soil type, but that is hardly representative of each soil type in the entire country. If we add to this the fact that the soil map has a scale of 1:1 000 000, any conclusions drawn from this study must naturally take the issue of scale into consideration.

Table VIII – A few physical and chemical characteristics of the soils in Continental Portugal

Unit-soil	Specification	Depth (cm)	Permeability (cm/h)	pH	Water capacity (mm)	Texture
Calcaric Cambisols		80	1.58	8.40	250.14	Loam
Chromic Cambisols		80	1.16	6.34	66.95	Clay loam
Calcaric Chromic Cambisols		80	4.17	7.66	83.87	Loam
Vertic Calcaric Chromic Cambisols		80	1.04	8.56	135.99	Silty clay loam
Dystric Cambisols		40	1.81	6.55	100.36	Sandy loam
Dystric Cambisols	Sedimentary post-Paleozoic rocks	40	1.81	6.55	100.36	Sandy loam
Dystric Cambisols	Ordovician shales and quartzites	80	1.49	5.93	179.34	Sandy loam
Eutric Cambisols	Eruptive rocks	60	2.59	5.33	87.11	Sandy loam
Eutric Cambisols	Post-Paleozoicas sedimentary rocks	80	1.49	5.93	179.34	Sandy loam
Eutric Cambisols	Ordovician shales and quartzites	80	1.49	5.93	179.34	Sandy loam
Humic Cambisols	Associated to Dystric Cambisols (eruptive rocks)	80	4.00	5.05	77.29	Loamy sand
Humic Cambisols	Eruptive rocks	80	4.00	5.05	77.29	Loamy sand
Humic Cambisols	Post-Paleozoicas sedimentary rocks	55	1.10	5.57	153.48	Silty loam
Humic Cambisols	Shales	80	1.81	5.11	125.63	Sandy loam
Humic Cambisols	Shales (associated to Luvisols, strong atlantic influence)	80	1.81	5.11	125.63	Sandy loam
Humic Cambisols	Shales (associated to Luvisols, strong atlantic influence)	80	1.81	5.11	125.63	Sandy loam
Humic Cambisols	Shales (associated to Luvisols, strong atlantic influence)	80	1.81	5.11	125.63	Sandy loam
Chromic Humic Cambisols		80	1.81	5.11	125.63	Sandy loam
Calcaric Fluvisols		80	4.00	8.04	218.69	Loam
Dystric Fluvisols		80	4.00	5.86	197.31	Loam
Eutric Fluvisols		80	4.00	5.86	197.31	Loam
Eutric Fluvisols	Associated to Calcaric Fluvisols	80	4.00	5.86	197.31	Loam
Eutric Lithosols		10	1.22	5.80	29.21	Loam
Eutric Lithosols	Associated to Luvisols	10	1.22	5.80	29.21	Loam
Eutric Lithosols	Ultrabasic rocks	18	1.49	6.80	34.75	Sandy loam
Vertic Calcic Luvisols		56	1.18	6.44	106.53	Sandy clay loam

Ferric Luvisols		70	2.59	6.15	159.10	Silty loam
Gleyic Luvisols		80	1.12	6.15	175.06	Sandy clay loam
Albic Gleyic Luvisols		80	1.12	6.15	175.06	Sandy clay loam
Orthic Luvisols		60	1.50	6.04	82.62	Loam
Plinthic Luvisols		70	2.59	6.15	159.10	Silty loam
Chromic Luvisols		80	1.20	5.00	173.14	Loam
Calcaric Chromic Luvisols		60	3.01	7.82	66.36	Silty clay
Vertic Calcaric Chromic Luvisols		80	0.46	6.59	91.16	Clay loam
Vertic Luvisols		80	0.77	6.80	205.30	Clay loam
Eutric Planosols		75	2.36	5.96	138.42	Sandy loam
Orthic Podzols		160	21.8	6.04	42.34	Loamy sand
Orthic Podzols	Associated to Calcaric Cambisols	160	21.8	6.04	42.34	Loamy sand
Orthic Podzols	Associated to Dystric Cambisols	160	21.8	6.04	42.34	Loamy sand
Orthic Podzols	Associated to Eutric Cambisols	160	21.8	6.04	42.34	Loamy sand
Orthic Podzols	Associated to Gleyic Luvisols	160	21.8	6.04	42.34	Loamy sand
Orthic Podzols	Associated to Eutric Regosols	160	21.8	6.04	42.34	Loamy sand
Rankers		55	1.81	4.40	155.89	Silty loam
Dystric Regosols		80	7.57	5.97	58.72	Sand
Eutric Regosols		80	7.57	5.97	58.72	Sand
Gleyic Solonchaks		80	0.52	5.80	219.61	Silty clay loam
Chromic Vertisols		80	5.66	7.24	141.72	Silty loam
Calcaric Chromic Vertisols		80	0.25	7.24	116.06	Clay
Pellic Vertisols		65	0.60	6.83	183.39	Clay
Calcaric Pellic Vertisols		60	1.05	7.60	156.64	Clay

If the goal was to classify soils as to their potential for use under irrigation, we found necessary to found this result on objective parameters: effective depth, permeability, ph and usable water capacity. Three levels were considered for each of these parameters: "Low aptitude", "Regular aptitude", "High aptitude (Table IX).

Table IX – Parameters and classes of soils aptitude for irrigation

Classes of aptitude for irrigation	Effective Depth (cm)	Permeability (cm/h)	pH	Usable Water Capacity (mm)
Low aptitude	< 20	<1	<5	<50
Regular aptitude	20-60	1-3	5-5,5 and >8,5	50-100
High aptitude	>60	>3	5,5-8,5	>100

Applying these criteria, and keeping in mind that specific Portuguese data was used to characterize these soil types, the following result was obtained (Table X):

Table X – Aptitude for irrigation of the Portuguese soils

Unit-soil	Specification	Depth	Permeability	pH	Usable Water Capacity
Calcaric Cambisols		H	R	H	H
Chromic Cambisols		H	R	H	R
Calcaric Chromic Cambisols		H	H	H	R
Vertic Calcaric Chromic		H	R	L	H

Cambisols					
Dystric Cambisols		R	R	H	H
Dystric Cambisols	Sedimentary post-Paleozoic rocks	R	R	H	H
Dystric Cambisols	Ordovician shales and quartzites	H	R	H	H
Eutric Cambisols	Eruptive rocks	H	R	R	R
Eutric Cambisols	Post-Paleozoicas sedimentary rocks	H	R	H	H
Eutric Cambisols	Ordovician shales and quartzites	H	R	H	H
Humic Cambisols	Associated to Dystric Cambisols (eruptive rocks)	H	H	R	R
Humic Cambisols	Eruptive rocks				
Humic Cambisols	Post-Paleozoicas sedimentary rocks	H	H	R	R
Humic Cambisols	Shales	R	R	H	H
Humic Cambisols	Shales (associated to Luvisols, strong atlantic influence)	H	R	R	H
Humic Cambisols	Shales (associated to Luvisols, strong atlantic influence)	H	R	R	H
Humic Cambisols	Shales (associated to Luvisols, strong atlantic influence)	H	R	R	H
Chromic Humic Cambisols		H	R	R	H
Calcaric Fluvisols		H	R	R	H
Dystric Fluvisols		H	H	H	H
Eutric Fluvisols		H	H	H	H
Eutric Fluvisols	Associated to Calcaric Fluvisols	H	H	H	H
Eutric Lithosols		H	H	H	H
Eutric Lithosols	Associated to Luvisols	L	R	H	L
Eutric Lithosols	Ultrabasic rocks	L	R	H	L
Vertic Calcic Luvisols		L	R	H	L
Ferric Luvisols		R	R	H	H
Gleyic Luvisols		H	R	H	H
Albic Gleyic Luvisols		H	R	H	H
Orthic Luvisols		H	R	H	H
Plinthic Luvisols		H	R	H	R
Chromic Luvisols		H	R	H	H
Calcaric Chromic Luvisols		H	R	L	H
Vertic Calcaric Chromic Luvisols		H	H	H	R
Vertic Luvisols		H	L	H	R
Eutric Planosols		H	L	H	H
Orthic Podzols		H	R	H	H
Orthic Podzols	Associated to Calcaric Cambisols	H	H	H	R
Orthic Podzols	Associated to Dystric Cambisols	H	H	H	R
Orthic Podzols	Associated to Eutric Cambisols	H	H	H	R
Orthic Podzols	Associated to Gleyic Luvisols	H	H	H	R
Orthic Podzols	Associated to Eutric Regosols	H	H	H	R
Rankers		H	H	H	R
Dystric Regosols		R	R	L	H
Eutric Regosols		H	H	H	R
Gleyic Solonchaks		H	H	H	R
Chromic Vertisols		H	L	H	H
Calcaric Chromic Vertisols		H	H	H	H
Pellic Vertisols		H	L	H	H
Calcaric Pellic Vertisols		H	L	H	H
Calcaric Cambisols		H	R	H	H

L - Low aptitude; R - Regular aptitude; H - High aptitude

IV. OTHER CRITERIA

Two additional criteria were used in the selection of regions with potential for irrigation: altitude necessarily below 800m (Fig. 14) and the frost-free period larger than 6 months (Fig. 15).

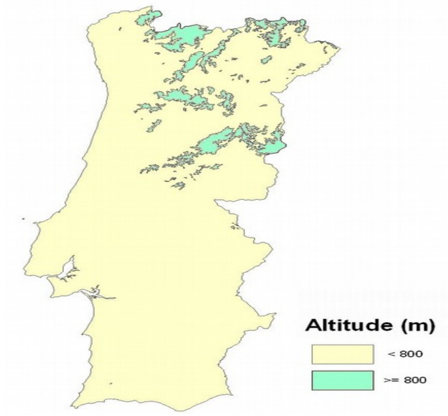

Fig. 14: Altitude of Continental Portugal territory

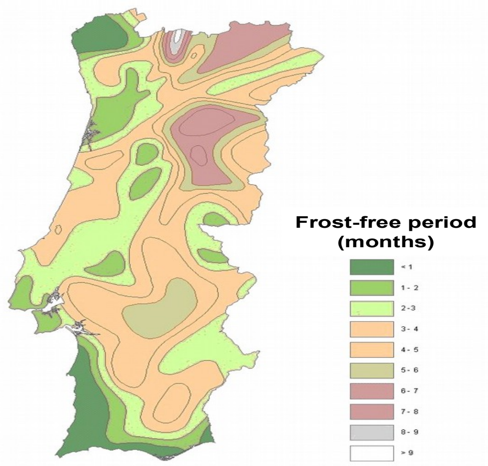

Fig. 15: Frost-free period of Continental Portugal territory

V. RESULTS AND CONCLUSION

As a result of the combination of all these criteria, the following map was obtained (Fig. 16), showing three classes of aptitude for irrigation: "Low aptitude", "Regular aptitude" and "High aptitude”.

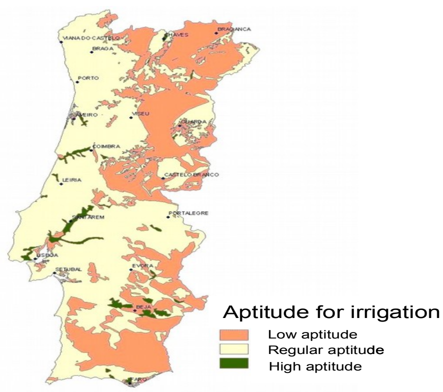

Fig. 16: Aptitude for irrigation of Continental Portugal territory

As a final conclusion of this analysis, we can say that the total surface of Continental Portugal (8.851.133,6 ha), can be divided in the following manner:

- 37,47% (3.316.950,9 ha) of Low Aptitude areas;
- 60,56% (5.360.281,8 ha) of Regular Aptitude areas;
- 1,96% (173.900,9 ha) of High Aptitude areas.

The potential gain derived from a hypothetical transition to irrigation is by far superior in the South and West of the Portuguese territory.

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