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Jornadas de reflexión sobre el Anexo IV de aplicatión para el Mediterrâneo Norte - Convenio de Lucha contra la Desertificación. Murcia (Spain), 22-23 May, 1997.

A PROPOSAL OF INDICES TO IDENTIFY DESERTIFICATION PRONE AREAS

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1 - INTRODUCTION

The present paper describes the recent achievements made by the Portuguese interdisciplinary team from the Convention to Combat Desertification (CCD) in the field of desertification prone areas identification, with emphasis to the water and land degradation related components where the Portuguese Institute for Water (INAG) is strongly involved.

The guidelines from CCD at this initial stage have been basically to come up with a methodology for identification of regions with different degrees of land degradation (from not yet degraded, or only slightly degraded, to severely degraded areas) as part of the recommendations from the United Nations Conference on *Environment and Development* in Rio de Janeiro (Chapter 12).

The immediate goal of this identification is to pave way to another UN Conference's recommendation (under the program areas): the definitions of programs to combat desertification that should in turn be integrated into national development plans and national environmental planning.

Any methodology to cope with this issue that proves to be both easy to apply (requiring readily available basic data) and scientifically sound will surely be extremely portable to other countries, helping in turn to reach a *harmonized description* of a phenomenon that transcend national boundaries.

The current proposal attempts to incorporate these recommendations and is based on the combination of three different indices, each of one reflecting specific processes related with desertification that bear a direct link with the water domain:

- the first one gives a measure of the average water availability within a region, if possible reflecting the moisture conditions in the soil and the stress attached to its deficiency;
- the second gives a measure of soil loss and its relation with land cover, soil type, slope and rainfall erosivity;
- the third gives a regional description of drought phenomena and its severity.

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In the next paragraphs a detailed description of the methodology to identify areas of intervention to combat desertification is produced along with the results of its application to the Portuguese territory which is a very complete “natural laboratory” for its experimentation since it covers an area with latitudinal development that is more likely to display different climatic zones, soils and geomorphology.

All the data used, numerical or cartographic, are part of the portuguese information system on water resources (SNIRH) based at INAG.

2 - METHODOLOGY

As previously mentioned the methodology for identification of intervention areas for desertification combat is based on the combination of three indices, each of one attached to one important water related field in the desertification process, using mainly GIS (Geographic Information Systems) tools. Other subjects related to the desertification process but exhibiting weaker links with the water domain (e.g. the economic and the demographic component) are here upon called indicators and dealt with later in this paper.

One of the main drawbacks of a methodology build over indices is its degree of subjectivity. Yet the desertification phenomenon is subject to a broad field of definitions according to specific regional characteristics that difficult a harmonized characterization.

The objective of this indices proposal is thus to group the more determinant physical processes involved in desertification in less subjective indices, leaving the regional specificity for the final weighting of such indices. This does not imply that each index has not several subjective aspects in itself but it was tried that a coherent rationale was attached do their development in order to be sure that small instabilities in each component do not reflect in the bulk response. The seeking of a robust combination method was thus a constant priority.

Climatic index

As already mentioned one of the indices should measure the average water availability within a region, if possible reflecting the moisture conditions in the soil and the stress attached to its deficiency. This index was named the *climatic index* and was defined, in a first stage, as being the ratio of the average annual rainfall to the average annual potential evapotranspiration calculated by the Penman method. Three classes were then defined, each related to a specific climate and with the weights described in Table 1.

Table 1 - Climatic index

P/ETP	CLIMATIC ZONES	CLIMATIC INDEX
> 0,65	Humid	1
0,5 - 0,65	Dry Sub-Humid	2
< 0,5	Arid and Semi-Arid	3

Figure 1 displays such index for the Portuguese territory where 87 meteorological stations were used. Not all of them had enough data to determined the Penman estimate for a 30-year period but a correlation was build between the Thornthwaite value and the Penman estimate.
This relation was broken into two different periods (September to March and April to August) since the Thornthwaite estimates are known to underestimate more severely the potential evapotranspiration for higher temperature values.

This indirect method of determination of the Penman estimate is very helpful in keeping the portability of such index to other regions, since most of the meteorological stations in each country may not gage all the parameters included in the Penman formula.

In Figure 1 it was not used the class for Arid climates since this type is strange to the Portuguese territory.

Although such index is proposed by the UNEP as a first measure of the climatic stresses it does not reflect the water stresses attached to the soil moisture. One of the extensions of the proposed methodology is thus to re-define it in terms of the number of months the precipitation totals plus the soil moisture could not overcome the evaporative power of the atmosphere, obtained through a monthly based water balance.

Soil loss index

The second type of physical processes reflected in an index should be related to the soil loss and its relation with land cover, soil type, slope and rainfall erosivity. For such a description a combination of four components was proposed for the index:

- the rainfall erosivity component, defined as the 30-minutes rainfall intensity with a return period of 100 years;
- the edaphic component, according to the soil type;
- the vegetation cover component, attached to each specific vegetation type;
- the slope component, attached to a specific geomorphology;

Table 2 - Soil loss index components

- *Rainfall Erosivity Component*

INTENSITY VALUES (mm/h)	CLIMATIC COMPONENT VALUE
< 60	1
60 - 67,5	2
67,5 - 75	3
> 75	4

- *Edaphic Component*

SOILS	EDAPHIC COMPONENT VALUE
Fluvisols	1
Arenosols	1
Podzols	1
Vertisols	1
Phaeozems	1
Planosols	2
Luvisols	2
Cambisols	2
Solonchaks	2
Leptosols	3

- *Vegetation cover Component*

VEGETATION GROUPS	VEGETATION COMPONENT VALUE
Permanent Cover	1
Agricultural Land (ploughed)	2

- *Slope Component*

SLOPE CLASSES (%)	SLOPE COMPONENT VALUE
< 5	1
5 - 15	2
> 15	3

Most of the weights attached to each class on the components is qualitative and tries to enhance all the desertification determining factors. The fact that the final index is obtained through a product of all the components further exaggerates this determinant property.

One difficulty for generalizing this index to other countries with less meteorological data might be the rainfall erosivity component but, once again, there are already established relations between daily or hourly amounts to 30-minutes intensities. The 100-year return period was chosen as the most significant for a fine reproduction of the convective type phenomena.

As mentioned the final *Soil Loss index* is obtained by the combined products of each component spatially distributed, using GIS tools. This final *Soil Loss index* is presented under three classes with the weights displayed in Table 3.

Table 3 - Soil Loss index

VALUES OF INDEX 2	**CLASSIFICATION**
1 a 4	Low
4 a 17	Moderate
17 a 72	High

Drought index

The last type of physical processes reproduced in an index is related to the drought phenomenon, one of the specific water stresses that probably better describes the desertification process due to its long lasting and wide spread nature.

Since drought characterization suffers from some degree of subjectivity (similar to the desertification processes) depending on the nature of the analysis (meteorological, hydrological, agricultural) a simple methodology was used based on a threshold below which a point drought occurs.

The threshold value or truncation level used was given by a certain non-excedance probability of annual precipitation. The period of records used in this drought analysis was 1943/44-1994/95, which comprise important drought episodes, in the 40's, the 80's and the 90's. Several non-excedence probabilities were analised (1%, 5% and 10%) to separate different drought severity levels.

The regional spread of the drought phenomenon is given by attaching the area of the thyessen polygons of each rain gage that is experiencing the point drought. The thyessen polygons were build from 321 rain gages. The average polygons area is about 360 km^2 and the most representative one has 1034 km^2.

The droughts are then characterized by three different characteristics:

– the deficit considered both as a measure of drought *magnitude* (when defined either as the deficiency below the truncation level or its standardized expression towards the average rainfall) and also as a measure of drought *severity* (when defined as the ratio between the maximum deficit and the average deficit);

– the average number of years under drought (measure of drought *occurrence*), defined as the ratio of the number of drought years to the total number of years considered;
– the average drought affected areas (measure of the *areal coverage* or extent of the phenomenon) given by the average of the total areas under drought.

All these indices are displayed in map format, developed in GIS environment.

Other measures of the desertification phenomenon are to be further applied. They are here called indicators and listed in table 4.

Table 4 - Desertification Indicators

QUALITY INDICATORS
Chemical Deterioration
• Salinisation
Conductivity of saturation extract
• Alkalinisation
Percentage of Na in catin exchange capacity
Phisical Deterioration
Percentage of organic matter
Infiltration
Ground Water Deterioration
Conductivity and nitrates content on ground water

ECONOMIC INDICATORS
• **Activity Level**
Liquid margin per ha
• **Enterprise Level**
Average production costs per product
Return to land and administration work per ha and per working unit
Total utilization levels for the resources land, work and capital
Shadow prices for land, work and capital
Economic costs per unit, on changes intervals, of the relevant technical aspects, such as erosion, etc.

3 - CASE STUDY: THE PORTUGUESE TERRITORY

As said before what is going to drive the identification of the appropriate class intervals for the composite indices is the crossing of information from each index with the national perception of the desertification phenomena.

This step is where the "calibration" of all the previous data-driven analysis is performed. This means that this is also where most of the contributes from other countries'technical expertise is of much help for harmonization purposes.

For the Portuguese territory the next exhibits summarizes most of the findings of this work.

Figure 1 displays the climatic index where a percentage of 10% to be seen for the Semi-arid climates and 35% is attached to the dry sub-humid component; in short almost 50% of total area is subject to intervention (since both sub-humid and semi-arid are to be coped with).

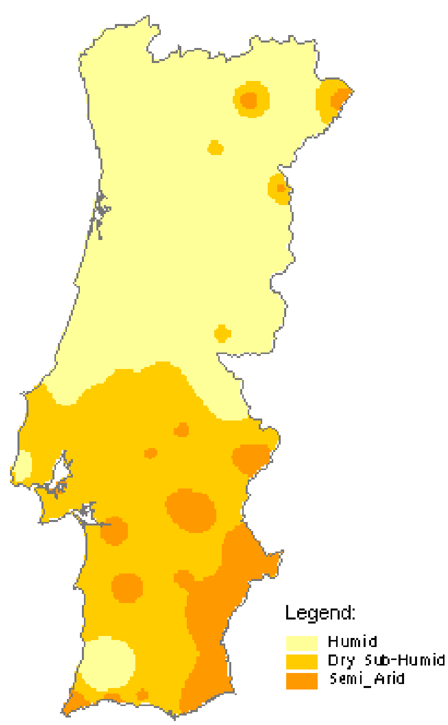
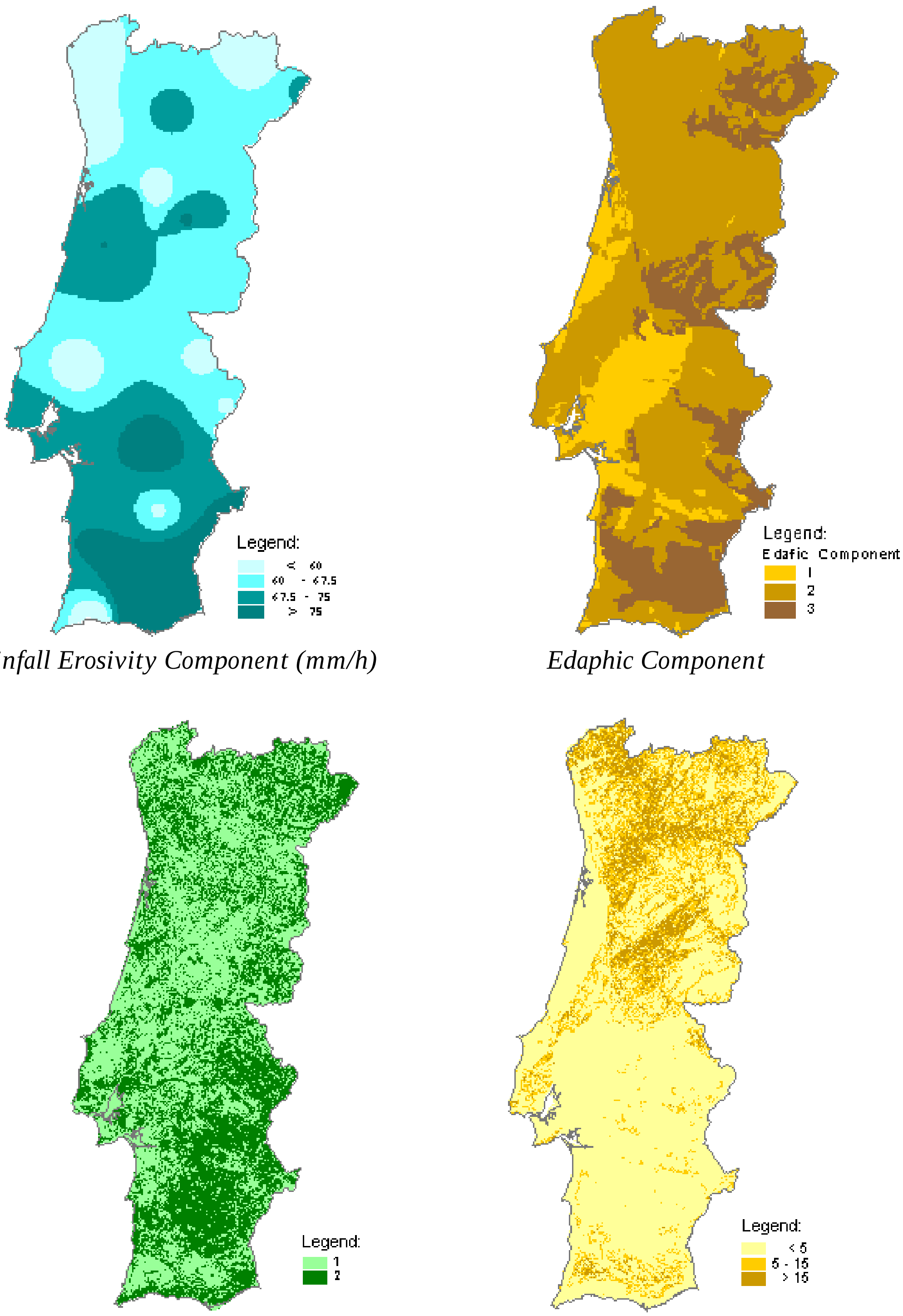


Figure 1 - Climatic Index

All the four components leading to the Soil Loss index are displayed in Figure 2. The fact that rainfall intensity was used as meteoric water instead of precipitation amounts (weekly monthly or yearly) not only highlighted the erosivity of rain but also refrain from considering multicolinerity in the index derivation process since precipitation amounts are strongly correlated in space with both altitude (and in a less degree with slope) and vegetation, turning the correlation process spurious.



Rainfall Erosivity Component (mm/h) *Edaphic Component*

Vegetation Cover Component *Slope Component (%)*

Figure 2 - Soil Loss Index Components

The combination of the four components through the arithmetic product is depicted in Figure 3, where a strong percentage is attached to the high rainfall intensities in southern Portugal and to the soils type. Less representative, because of less areal compacity, but still important to the soil index is an area in the NothEastern Portugal.

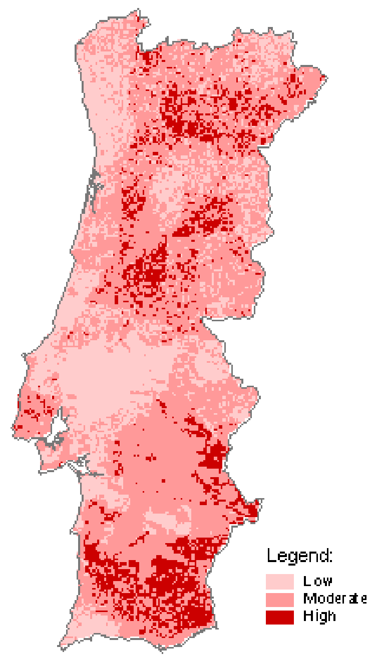
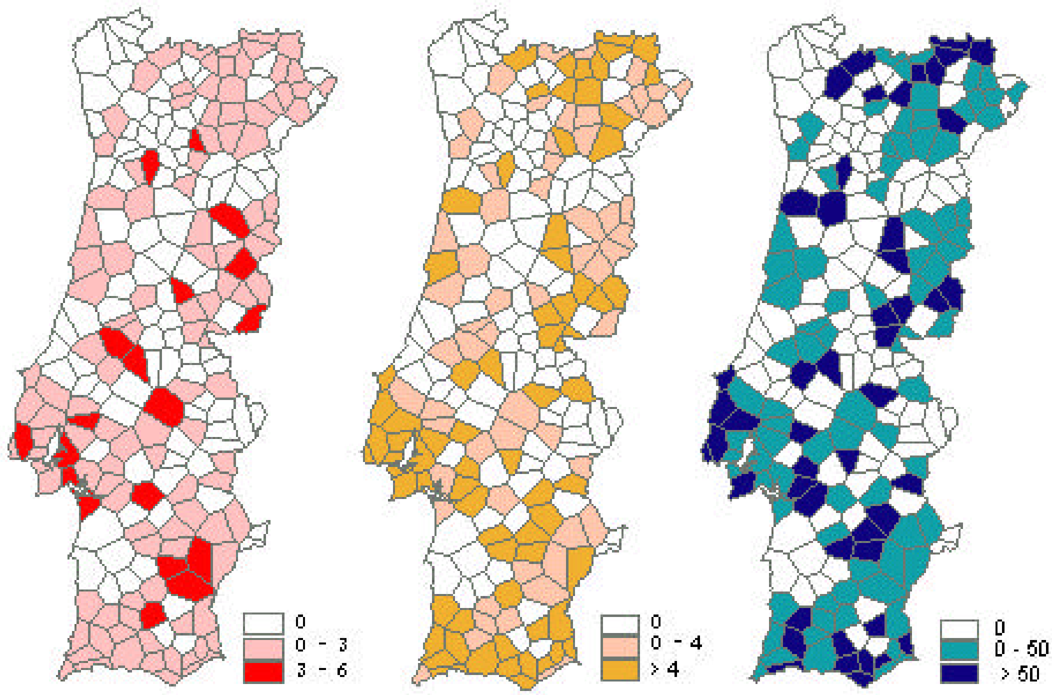


Figure 3 - Soil Loss Index

When identifying the non-excedance probability values the log-normal distributions proved to give good fitts to the annual rainfall data.

Figure 4 displays the areal spread of the drought phenomena when the two most significant characteristics of drought measures were used: its occurrence and its magnitude (this last considered independently or standardized by the average rainfall) when using data relative to the 1% truncation level.

From Figure 4 the drought durations (given by the average number of drought occurrences in the 1943/44-1994/95 period) were chosen as the best index for the identification of drought affected areas.



Average number of drought years (%) *Average Deficit/Average Rainfall (%)* *Average Deficit (mm)*

Figure 4 - Drought Index

4 - CONCLUSIONS

In the present paper a methodology is presented to help in the definition of desertification prone areas. This objective is obtained through the manipulation of three indexes each of one considering important desertification inducing processes related with the water domain.

The combination of the three indices (climatic, soil loss and drought), through the same GIS processes made previously when combining the components of each indices, is displayed in Figure 5. With this combination specific characteristics belonging exclusivly to each index were overshadowed while several degrees of simultaneous areal occurrence were highlighted.

In this way the most sensitive areas to the desertification processes identified were some zones in Alentejo, in southeasthern Portuguese territory and some zones further north (about 11%). Moderate risk to land desertification is observed in 60% of the Portugal territory.

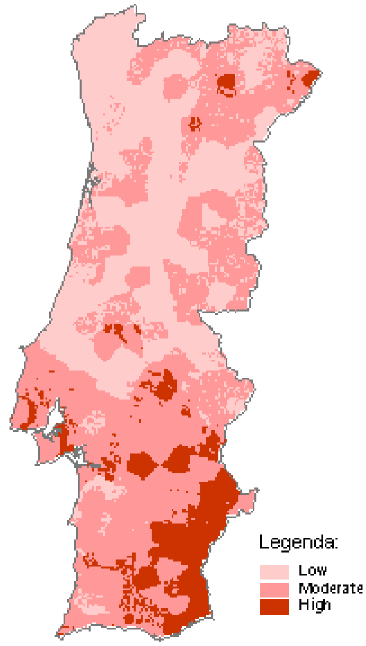


Figure 5 - Combinated Index

AGNOWLEDGMENTS

The authors wish to agnowledge the members of the Portuguese Scientific Committee from the Convention to Combat Desertification for the fruitful discussions that lead to the final establishment of this methodology.