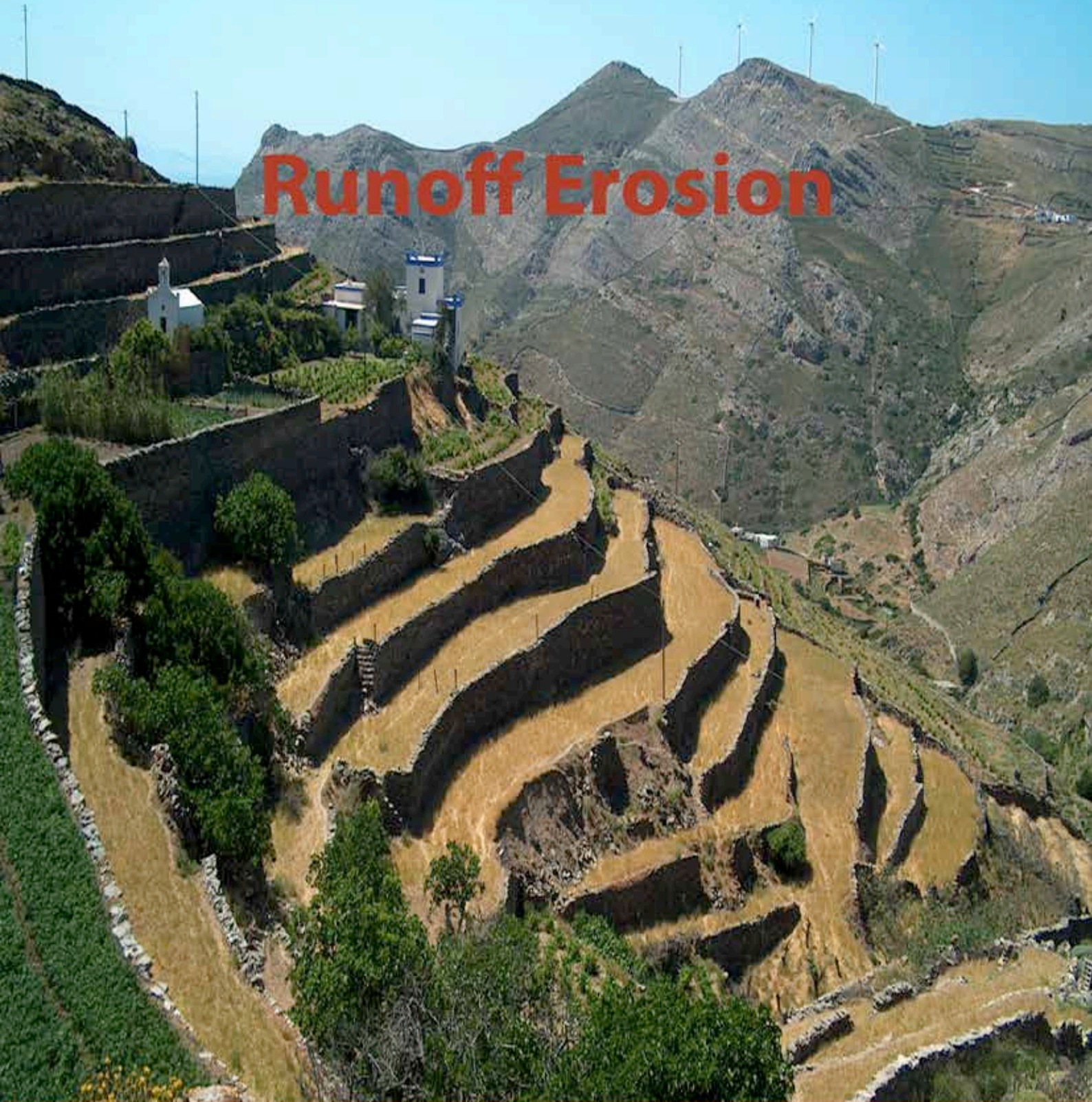


# Runoff Erosion



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## **PART II - CASE STUDIES**

# **CASE STUDY 7: RUNOFF EROSION IN PORTUGAL: A BROAD OVERVIEW**

**Tomás de Figueiredo**

## **1. INTRODUCTION**

Soils are generally a scarce natural resource in Portugal as far as productivity is concerned (CNROA, 1983; Agroconsultores e Coba, 1991; Agroconsultores e Geometral, 1995). In fact, the major part of the territory is potentially not suitable for agriculture, corresponding to areas with misuse and over-exploitation of the soil resource in cropland, and to typical marginal land cover by forests and shrubs (Fig. 1). The soils with moderate and high suitability are under agricultural use, more or less intensive, that take advantage of their productivity, but that partly experience incorrect management practices (Sequeira et al., 2012, this issue). Besides the crucial support of food and fiber producing activities, soil functions in ecosystems, either cultivated or natural and semi-natural, contribute in providing services and public goods that rise attention to management of large tracts of marginal areas, whilst tackling the problem of persistent population decrease and ageing in rural areas that lead to unmanaged land or abandonment, for instance with consequences for wildfire hazard and control (CIMO, 2009; Rosário, 2011). As so, poorly provided by good soils, enduring threat of several types all over the territory (with a large extent assigned to runoff erosion, CAN, 1980), Portuguese soils require knowledge and protection, to limit resource depletion, recover degraded areas and ensure sustainability of actual or foreseen land uses and soil-based activities.

This opening chapter of the Portuguese case studies presented hereafter aims at providing a general picture of runoff erosion distribution in Portugal, more precisely in the country's continental territory, adding further information in view calling attention to wider range assessments that rise awareness towards natural resources degradation trends, and sustainable land use and management.

A review on the topic of soil erosion in Portugal has been published by Coelho (2006). It is therefore a recent and comprehensive review of relevant research and broad approaches to the identification, quantification and distribution of the problem

in Portugal, up to that date. The following text takes Coelho (2006) as a reference information base, that is summarized here and to which is added new information, issued from more recent research and other developments carried out at National level.

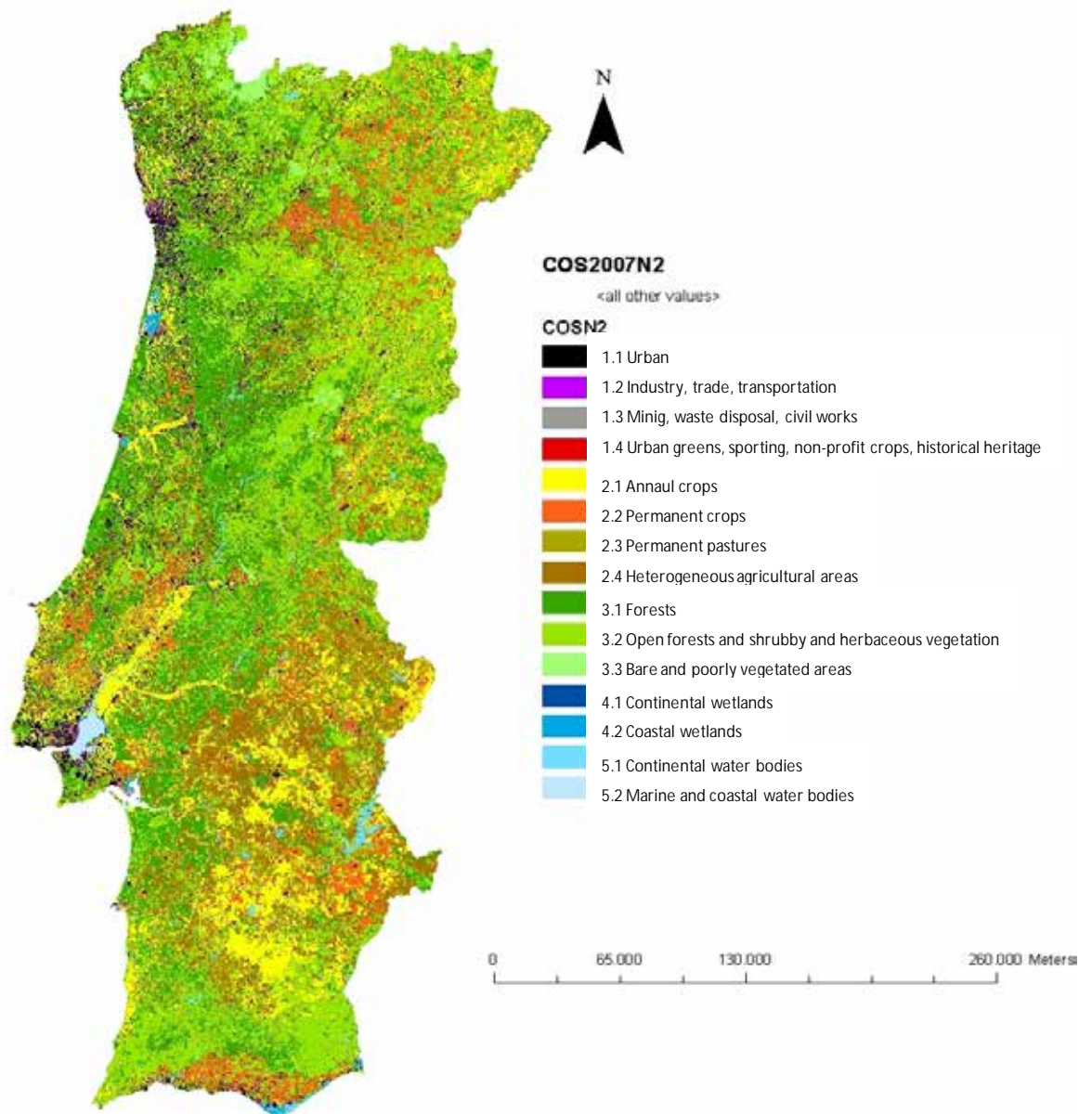


Fig. 1: COS2007 – Land use and cover map of Continental Portugal 2007 (IGP, 2007).

## 2. CONTINENTAL PORTUGAL: NATURAL SETTING AND LAND USE

The Portuguese continental territory is a land of contrasts, where the Tagus River splits apart the Northern hilly country from the lower lands of the Southern half (Fig.

2). In fact, north of the Tagus, 75 % of the territory is above 200 m elevation, with an average altitude of 370 m, while the southern tract of the country the mean elevation is 160 m, with 62 % of the area below 200 m (Medeiros, 1987; Medeiros, 2005). Very few mountain ranges exist in the South, the highest peak hardly surpassing 1000 m (Serra de S. Mamede, 1027 m), but the top of Serra da Estrela, north of the Tagus, in the Central Massif, approaches 2000 m (1993 m). The most impressive mountain ranges are aligned from NW, near the coast, to Southeast, inland. This general physiographic picture readily indicates a geomorphologically active natural setting, in which hill-slope processes as runoff erosion play an important role.

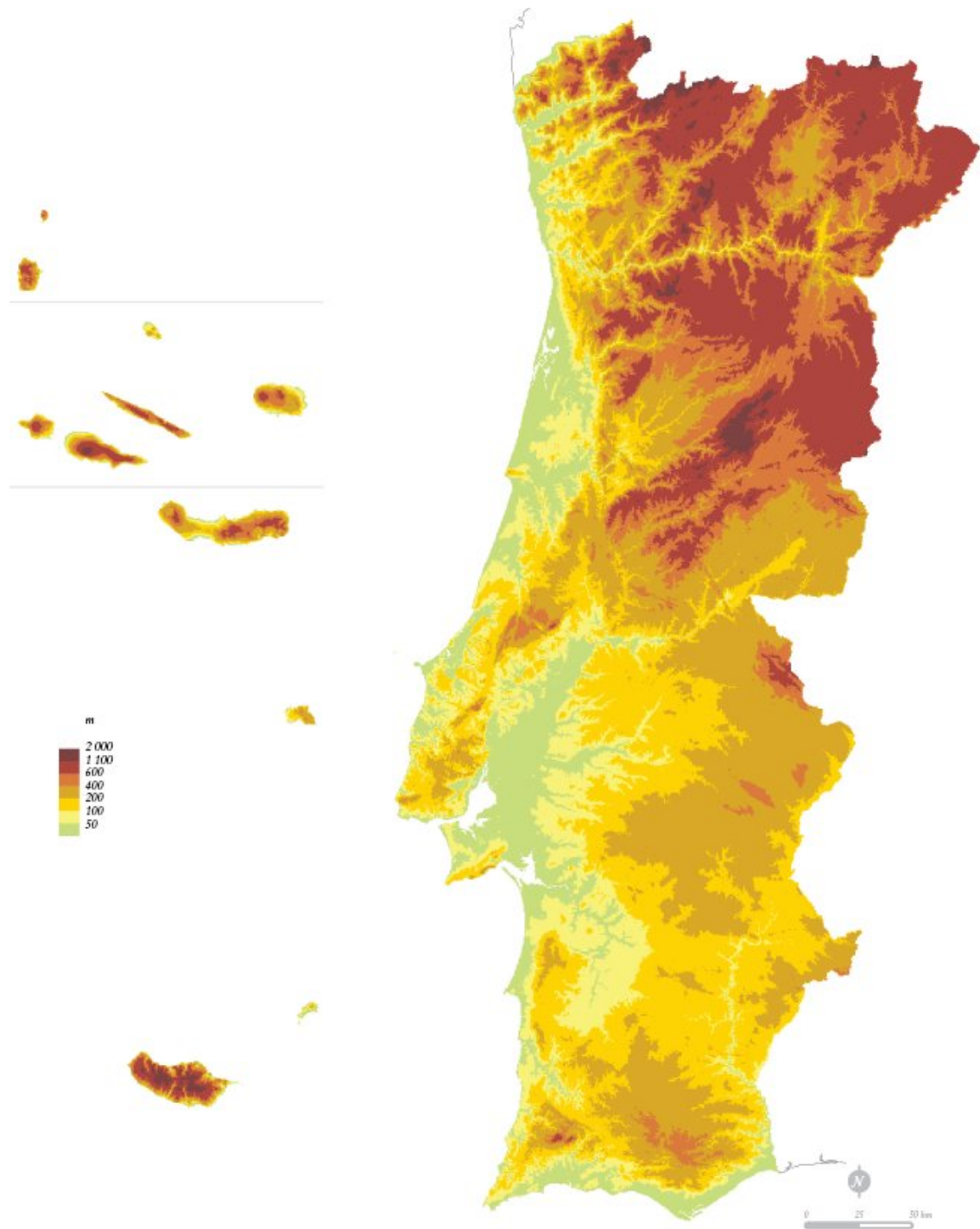


Fig. 2: Hypsometric map of Portugal, 1:1 000 000 (CNA, 1980).

Precipitation in Portugal ranges widely, from around 300 mm annual average in the NW near-coast mountain tops (the rainiest spot in Europe), to below 500 mm in the Southern region of the Algarve and in inland areas of the deep Douro valley (Ribeiro, 1986). Factors generally affecting rainfall spatial distribution are latitude, altitude and continentality, coupled to outcome quite contrasting areas a short distance apart. As typical of the Mediterranean climates, rainfalls are scarce in summer, and mainly

concentrated in autumn and winter, and inter-annual variability is very sharp (coefficients of variation of annual precipitation reach 30% about the mean, Lencastre & Franco, 2006). As annual precipitation amounts decrease in the territory, rainfall concentration increases (Daveau, 1977) and, therefore, higher intensive rainstorms occur in drier areas when compared with the wetter ones, meaning more severe consequences in terms of runoff erosion. In fact, and in average terms, while for the more humid areas of Northern Portugal values of the annual rainfall erosivity index (R or EI30, in SI units) may be assumed roughly similar to that of annual precipitation (in mm), this relationship does not stand for the whole country, as in drier areas of Southern Portugal they may reach about the double of annual precipitation values (Figueiredo & Gonçalves, 1990; Figueiredo, 2001; Tomás, 1997).

In about 3/4 of the Portuguese continental surface the ancient geological basement (the Hesperian Massif) outcrops metamorphic rocks (Palaeozoic schists) and magmatic rocks (Variscan granites). A centre-western belt together with the south facing Algarve ones are Meso-Cenozoic terrains, where Secondary limestone and more recent sedimentary rocks outcrop (including sandstones, marls and clays). The third main structural unit of Continental Portugal is the Tertiary Tagus basin, a depression of the ancient basement filled in with thick layers of loose sediments (Ferreira, 2005).

Soils derived from these parent materials are for the most acid and very acid, except in the calcium carbonate rich or basic lithologies (Varenes, 2003). Also, where hard rock basements of schist and granite dominates, soils are shallow, coarse (in granites) or medium texture (in schists) and incipiently developed (Leptosols, Regosols), especially in the highlands North of the Tagus river, corresponding to marginally suitable or unsuitable areas for agriculture (Fig. 3). In the higher altitudes, soils generally depict a much higher carbon content in the surface horizon than those of the lower, drier and hotter lands, while in gentler slopes deeper soils may develop (Cambisols, Luvisols or Alisols) (Agroconsultores e Ciba, 1991; Agroconsultores e Geometral, 1995). On the sedimentary lithologies of the Meso-Cenozoic belts and Tertiary Tagus basin, where slopes are gentler, under milder and drier climatic conditions, deeper and well developed soils dominate (Cambisols, Luvisols, and even Mollisols). This is also the case in the few volcanic or micro-crystalline rocks outcrop, as basalt (Lisbon) and micro-gabbros (Beja, Alentejo)), where finer

textures are common, often with internal drainage problems (Vertisols), nevertheless highly suitable for agriculture. The deeper Portuguese soils are the incipient Fluvisols better represented in the main rivers flood plains (Mondego, Tagus and Sado), with very high suitability for agriculture (Cardoso, 1973; CNROA, 1983). In most of the country, soils are weakly structured and carbon contents are low, with the exception of highland soils mentioned above. In brief, soils with lower erodibility correspond to the coarse textured, permeable (granite derived in most cases), rich in organic matter (in the highlands), while the most erodible ones are silt loams, poor in organic matter due to drier and hotter climate and land use and management practices (typical of the schist areas of the Hesperian Massif but also of the sedimentary carbonate rich areas of the Western Meso-Cenozoic belt) (Ricardo, 1980; Figueiredo, 1990). Rock fragments are a common feature in Portuguese soils and they contribute to visibly reduce potentially high fine earth erodibility (Poesen & Lavee, 1994; Figueiredo, 2001).

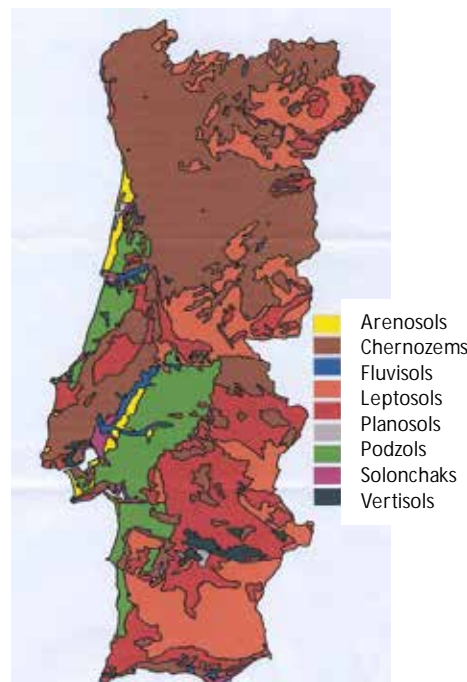


Fig. 3: Soil map of Portugal, 1:1 000 000, FAO/UNESCO legend (CNA, 1980), simplified.

As a Mediterranean country, Portugal depicts the typical natural vegetation communities that characterize this ecological region, and roughly follows the same land use patterns as other countries in the Mediterranean, even though largely contrasting vegetation cover are found in a deeper and more careful insight (Ribeiro,

1986). In 2000, the territory was roughly halved in forest uses (including agro-silvopastoral and shrubs) and agricultural land use (including pasture land) (Painho & Caetano, 2006.). Native forest cover, based on the oaks, *Quercus* (*Q. pyrenaica* and *Q. robur* in humid and colder areas; *Q. suber* and *Q. rotundifolia* in the hotter and drier areas) is poorly represented and so, most forest land are planted stands, where *Pinus pinaster* and *Eucalyptus globulus* are the dominant. Even though forests provide a very effective soil protection, hazardous forest management practices are common (installation and, timbering operations, infrequent clearance inducing fire hazard, for instance), which turn forest land into important sediment sources instead of soil retention areas (Agroconsultores e Caba, 1991; Coelho 2006). On the other hand, the key Mediterranean crops are also present in large extent in Portugal – winter cereals, olive groves, vineyards – to which must be added mixed farming systems, where cattle, grazing areas, annual and permanent crops are arranged under a single farm yet split in parcels, as it is the case of large areas in the North of Portugal. Scrubland, included in the forest land use major type is very significantly represented in continental Portugal, the latest assessments indicating about 36 % of the total area (CIMO, 2009). Land cover is changing rapidly in the last decades, as in the last decade of 20<sup>th</sup> century agricultural land use proportion decreased and forest land use increase (less 84 thousand ha and more 12 thousand ha, respectively), a trend that persisted during the first decade of the 21<sup>st</sup> century (yet not quantified) (Painho & Caetano, 2006; see Fig. 1 for the 2007 assessment). Furthermore, abandonment and intensification go side by side, eventually in different environments, as shown by the increase in scrubland areas as well as that of new permanent crop plantations, namely olive groves. Signs are contradictory as far as soil protection is concerned, because the decrease in the less protecting areas as that of agricultural land uses is followed by more intensive cropping systems and, on the other, the global increase in forest land use means an increase in scrubland, invading former cropland and grazing areas, now non-managed land tracts where social control does not prevent natural or human induced hazards (as wildfires).

The indicated ranking of land use types according to the protection of soils they may provide bears on the assumption that regular management practices are associated with such land use types, at the farm or small rural community scales. However, soil and crop management practices play a decisive role in the actual soil

degradation trends or soil protection status a certain land use type endures (Morgan, 2005). Furthermore, when wrong management practices are applied cropping systems over unsuitable soils, soil degradation is magnified (e.g. Agroconsultores e Coba, 1991) and an extreme example exists to prove it in the Portuguese recent history that was labeled as the wheat campaign (Coelho, 2006). The rapid increase of cereal production promoted in the 30's and 40's of last century, under a policy based on the self-sufficiency paradigm, lead to extended shrub replacement by cereal fields, in unsuitable sloping land, with disastrous consequences for land productivity and soil erosion, which still persist in the Alentejo inland, where degraded soils did not recover yet, while scrubland invaded back these areas.

Actual European agricultural policies their translation in national regulations accommodate a series of programmes directly or indirectly addressing runoff erosion control (as the package of agri-environmental measures). Good management practices are promoted through financial incentives provide under cross-compliance schemes, focused on pasture land, grassed lanes in permanent crops, conservation tillage practices, integrated production and organic farming (INGA webpage). As well, incentives were given to convert abandoned farmland into afforested areas that are continued for long time after installation, to ensure application of good forest management practices persist during stands life, as it is the case of clearance and other silvicultural procedures (IFADAP webpage,). Yet, not only adequate control on the application of such measures may lack but also a part of the territory falls out of the range of these measures. Furthermore, in cases policies do not encompass the fast land use changes and perspectives the Portuguese territory is experiencing. Actual major threats to soil resource are those associated with the hydrological consequences of wildfires in marginal lands, while in cropland, traditional intensive tillage operations cause structural degradation of soils, decline in organic carbon soil storage and increase runoff erosion risk (Coelho, 2006; Carvalho, 2012, this issue).

### **3. SOIL DEGRADATION ASSESSMENTS**

This section summarizes information regarding soil degradation assessments, namely due to runoff erosion, performed for continental Portugal, most of which reported by Coelho (2006) in her review on the topic. Therefore, it follows closely

this reference, but it adds also new information issued from more recent works. It addresses experimental results and maps, following presented, briefly commented; consistency of assessments and their interpretation is also shortly commented.

The Vale Formoso, Alentejo, erosion experimental centre has the longest record of soil loss in Portugal (three decades), assessed in reference Wischmeier erosion plots, under traditional and alternative crop rotations, typical of the southern rainfed cereal based cropping systems (Roxo, 1994; Tomás, 1997). Average soil loss on plots cultivated with winter cereal did not exceed 2 t ha<sup>-1</sup> y<sup>-1</sup>. A set of plots were also installed in another very important agricultural region: the Douro valley, with vineyards in very steep slopes and stony soils (Rosa, 1981). Records were deeply explored for the first ten years after plot installation and average soil loss did not exceed 0.5 t ha<sup>-1</sup> y<sup>-1</sup> (Figueiredo & Ferreira, 1993; Figueiredo et al. 1998; Figueiredo, 2001). These are the longer and most significant monitoring stations and they were set under a national programme for assessing erosion rates and erosion control measures efficacy in the main agricultural land use types, following evidences throughout the country of large areas were under soil degradation process or already degraded.

Apart from these, most of the field studies that provided data on soil loss rates are short duration experiments carried out within research project activities. They include field plots, normally small scale ones, gully erosion measurements, field surveys and field rainfall simulations, the latter being largely dominant. As expected, experimental conditions very much affect results obtained, but they allow interpretations on the erosional response of different land uses (crops, forests, shrubs, burnt areas). Coelho (2006) discusses these data, concerning the team from the University of Aveiro, mainly focused on wildfire effects in forests (authors involved are Coelho, Ferreira, Shakesby and Walsh in work indicated in the references list), and the team of Poesen, including the author of this text (Poesen, Vandaele, Vandekerckhove I references list), mainly focused in gully erosion in arable land. Further research performed in Portugal includes more recent studies by Figueiredo et al. (2011). Bompastor et al. (2009) and Fleskens & Strosnider (2007), focused in young forest plantations, shrubland and olive groves, respectively.

All field studies considered, a consistent trend in results is that soil loss rates are normally below expected for the prevailing site erosion factors. However, very much higher soil loss rates are recorded under intense and less frequent rainfall events, pointing out the importance of thresholds in erosion processes. They also point out the need of further research, still lacking in certain land cover types, and to a more careful attention to forest areas in what concerns soil protection.

Maps at national scale show large tracts under severe risk, namely the inland belt from North to South, yet much wider in Alentejo. This risk regards directly or indirectly runoff erosion as some of the national assessments focuses on soils, climate, vegetation and desertification. Besides such surveys, model outcomes as that of PESERA (Kirkby et al, 2004) provide also a picture of the potential risk of the territory. Generally, map interpretations match with interpretation developed in the previous section, based on the natural and land use conditions. Figs. 3 to 6 support and illustrate these general comments.

Indications provided by maps are mainly qualitative but, nevertheless, they normally do not match with the experimental quantitative approaches. Besides methodological inconsistencies that might be found when comparing the different approaches followed to study the same problem, scale is critical issue in erosion research. Furthermore, as complex processes are involved, with dynamic thresholds, erosional response to certain experimental conditions may fall well apart from expectable. On the other hand, most data basis that feed information to built up maps neglect a crucial soil feature that largely controls erosion rates and that is widely represented in the Portuguese soils, namely in the areas where erosion risk is more severe: the coarse fraction of soils, composed by rock fragments, roughly qualified as soil stoniness. This feature is sometimes also neglected when discussing experimental results. It is important to note that, as rock fragment increase in soil surface due to selective erosion of fines, therefore indicating that soil is under threat, the lower can be the soil loss rates measured due to the increasingly higher soil protection they provide.

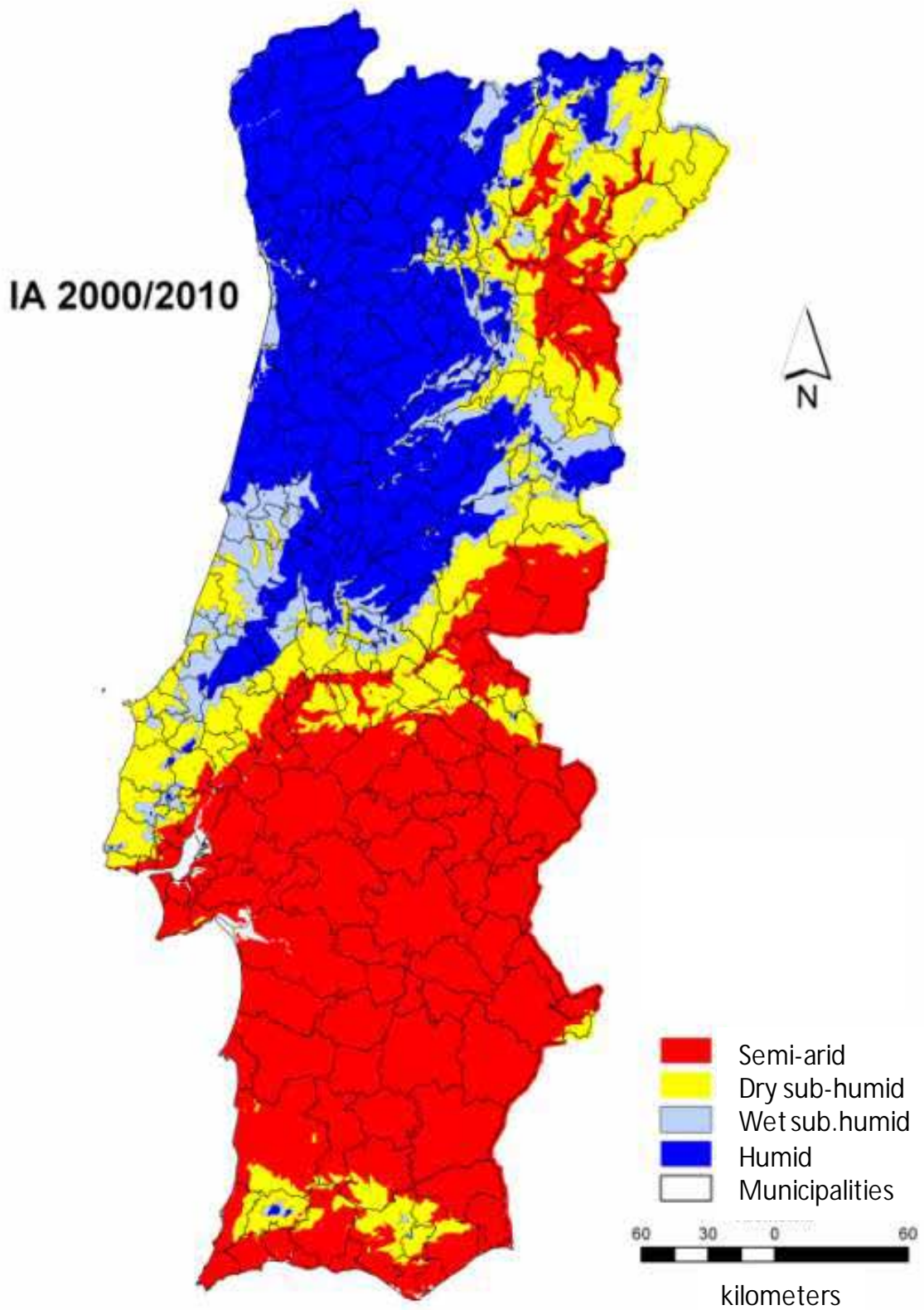


Fig. 4: Desertification susceptibility, assessed by the Aridity Index (IA) for Continental Portugal, 2000/2010 (PFNCNUCD, 2011).

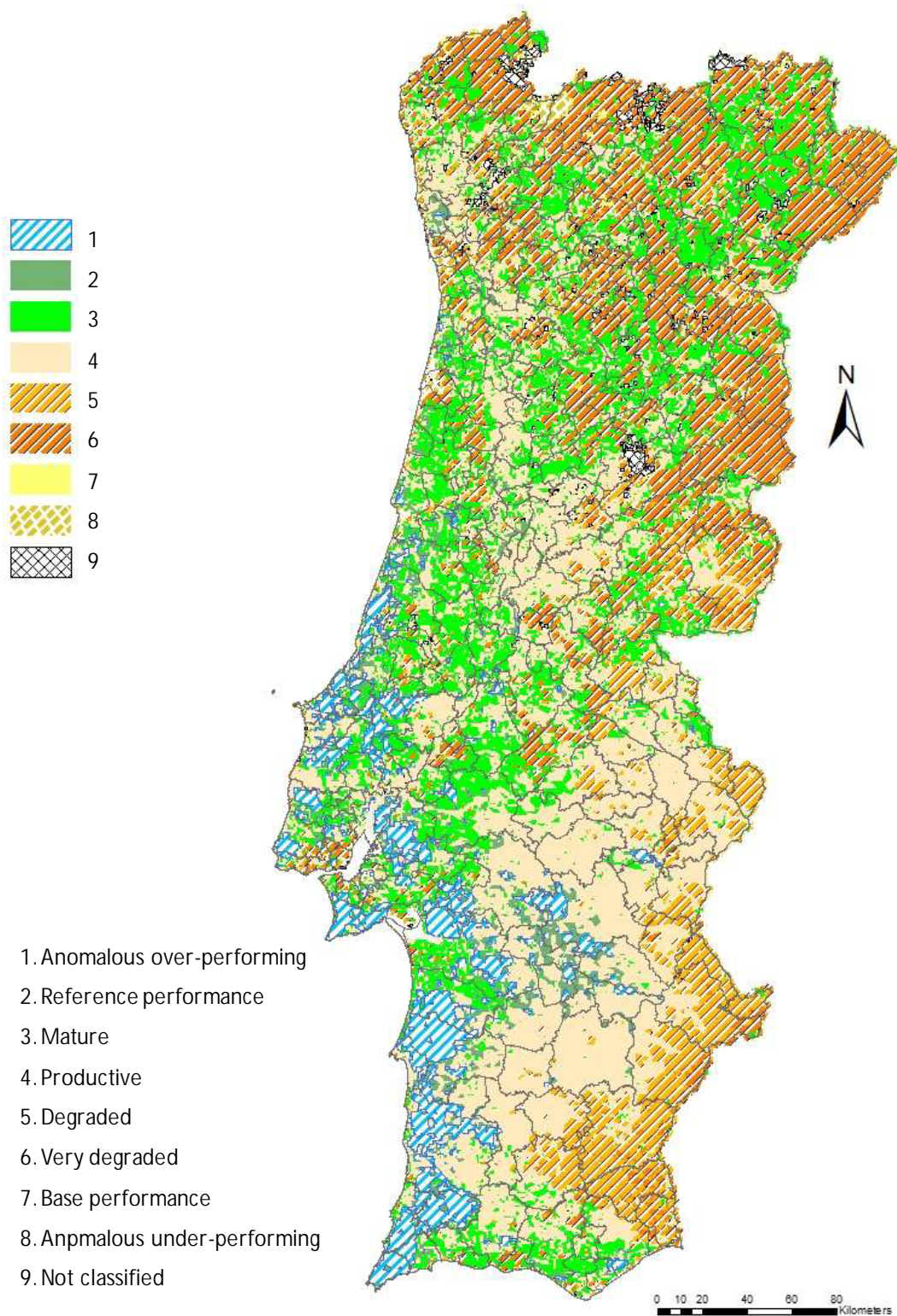


Fig. 5: Land Degradation Index (LDI) – Land quality status, for 2000/2010, in Continental Portugal, following Sanjuan et al., 2011 (synthesis by Rosário, L. do, National Focal Point of the UNCCD).

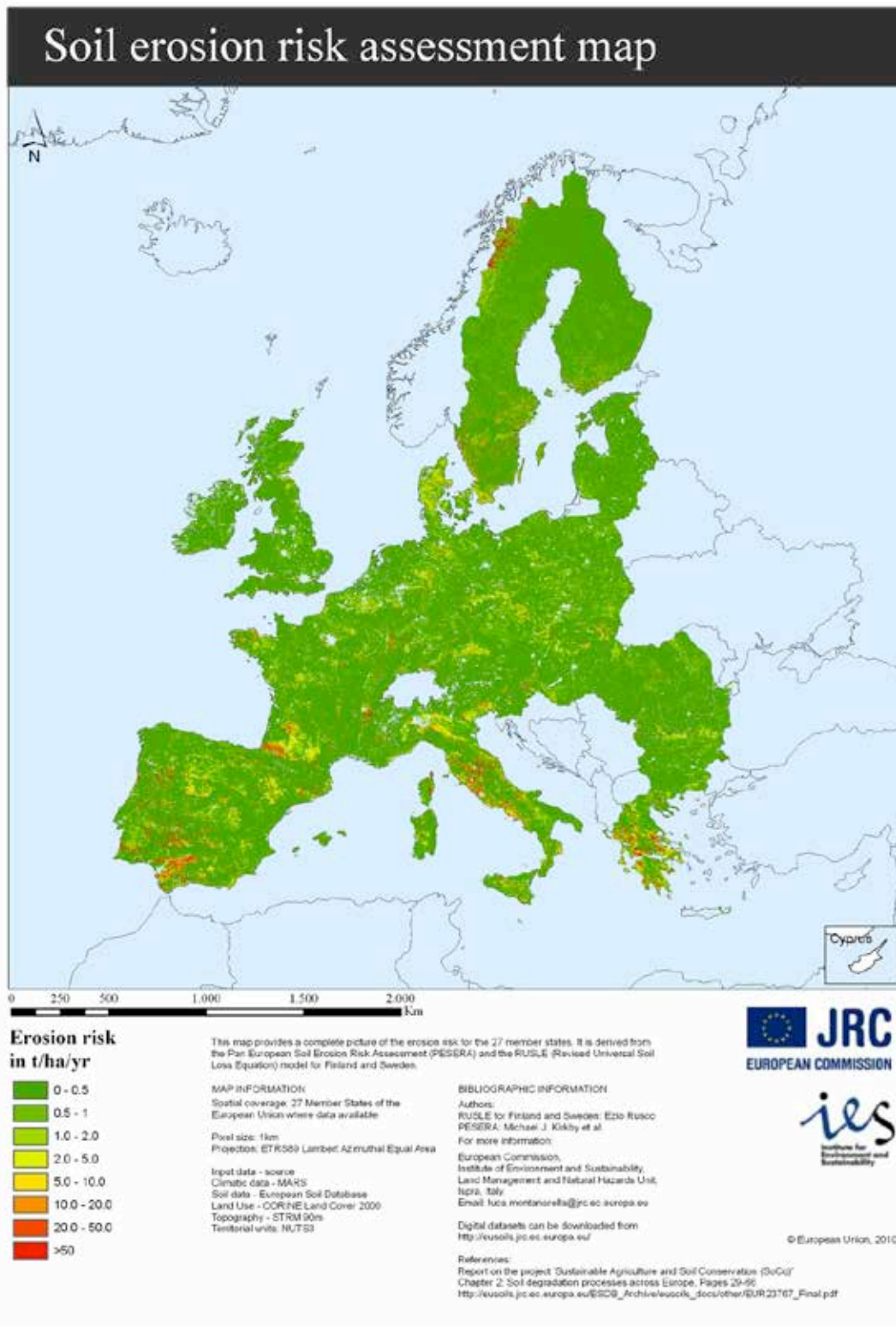


Fig. 6: The PESERA map of erosion risk for Europe (Kirkby et al., 2004).

#### **4. FINAL REMARK**

The Portuguese continental territory is highly diverse in what concerns physiography, climate and soils but, may generally be considered prone to high runoff erosion risk under the prevailing natural conditions. Land use and management, again quite variable along the country, and besides the good examples of soil protection in practiced in certain areas and cropping systems, do not help controlling that risk. Although trends of change towards climatic aridity eventually foreseen, and trends towards a new land use paradigm present scenarios that might enlarge the areas under risk, increasing awareness by farmers, land users and the global community are expected to help improving land management practices and models for a sustainable resource use, namely soil and water. This awareness should be translated into policies and regulatory actions, in a comprehensive Soil Act at national level, within the framework of the much expected European Soil Directive, still lacking consensus.

#### **5. THE SELECTED CASE STUDIES**

In spite of the general approach followed in the book, namely a focus on runoff erosion, the Portuguese case studies selected also address to a larger or shorter extent management practices following soil conservation principles. In fact, it is essential that, once identified soil degradation, solutions issued from well grounded research contribute to tackle the problem and point towards sustainable resources management and conservation within the framework of actual productive activities carried out in a living territory. As so, rather than a simple focus on runoff erosion research outcomes, article presented hereafter include results of research oriented towards sustainable management of farm land and afforested areas, that may taken as examples to better ground recommendations for practical application or policy design.

The four case studies cover distinct geographical settings (two in the North and two in the South of Portugal), and cover agricultural (3) as well as forest (1) land uses. The Douro valley vineyards are an example of the risks associated to permanent row crops cultivated in the extremes of such regional setting, and of the way a deep knowledge of local conditions provides solutions for tackling those risks. The largely negative experience of adopting inadequate practices and models in cereal cropping throughout the country but especially in the South, fully justifies the attention given to

this type of land use in two case studies, where good management farming practices adopted in conservation agriculture, clearly show how wrongly managed were past but still prevailing farming systems. The last case study addresses the topic from the side of recovery of degraded land by intense cereal cropping, performed within an active farm, that is is a known case study of sustainable farming. Forest cover provides a most efficient way to control erosion but, under Mediterranean conditions, suitable site preparation is required to improve soil quality, therefore, ensuring success in installation and growth of new forest stands, a topic addressed to in the second case study selected, that not only highlights the importance this so widely represented land use type but also addresses a crucial moment of forest stands life – the installation phase. The set of selected case studies is intended to contribute to a reliable picture of research carried out in soil protection in Portugal.

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