The Portuguese National Ecological Network - A mapping proposal

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Introduction

In Portugal, the Ecological Network (EN) was included in the Portuguese legal system in 1999 according to which it must be considered, delineated and implemented in all landscape plans at all spatial scales. Despite of all EU policies, in Portugal the EN is defined by the set of areas, values and key systems for environmental protection (article 14th of the Decree Law n. º 46/2009). Furthermore, at national level there is only the Program for National Planning Policy, which doesn't include any EN delimitation.

This paper presents a methodology for the delineation of the National Ecological Network (NEN) based on: a) the physical sub-system which refers to physical components and their interactions; b) biological sub-system composed by habitats and flora; c) the network concept which is based on the vertical and horizontal connection of structures and information within the ecological system (Jongman, 1995; Magalhães, 2001). Moreover, the main notion of EN is to link ecosystems into a spatially coherent system through which materials and organisms flow (Opdam et al., 2006), as reflected in the Landscape-System methodology (Magalhães et al., 2007).

The Portuguese ecological networks, at different scales, has been developed according with the theoretical research and actual field of studies carried out by the Landscape Architecture Research Centre (CEAP/ISA/TUL) since the beginning of the 90s, and is closely related to the ecological landscape planning methods and policies adopted in European countries. The CEAP/ISA/TUL is developing a research project, funded by the Foundation for Science and Technology's, aiming the proposal of a methodology for mapping and policies implementation for the NEN (Project reference: FCT-PTDC/AUR-URB/102578/2008).

The main goal of this paper is to present the NEN methodology as a component of the Landscape-System methodology (Magalhães et al., 2007) whose objectives are the maintenance, restoration or enhancement of nature conservation and biodiversity within a coherent system, safeguarding ecological and cultural values, complemented with potential multiple uses and respective evolution tendencies.

This study will focus on the NEN and will compare it with the regional and local case studies at scales 1/100.000 and 1/25.000 respectively.

Background and Literature Review

Ecological networks represent one of the most widely applied concepts in current approaches to nature conservation (Harfst et al, 2010). Nevertheless, about 82% of EU territory is falling outside the Natura 2000 network (EC/CIRCABC, 2012) and the natural habitats in many European cities are fragmented due to historical socio-economic and land use changing processes

(Jongman and Pungetti, 2004), including transportation infrastructure (ECNC, 2003; Forman et al., 2003; Tillmann, 2005). Consequently, landscape fragmentation (Jaeger *et al*., 2011) and homogeneity, due to dispersion of habitat patches and small size corridors ignoring the quality of the matrix (Forman, 1995), are important factors to consider in biophysical resources conservation, biodiversity and ecological continuity. Therefore, the need of creating green continuities became a reality since the 19th century with Olmsted, Arturo Soria and Mata's Linear City, and Ebenezer Howard's Garden City (Magalhães, 2001). However, park creation and nature conservation took place in what was left remnant or unused. Nowadays, it is accepted that protected areas alone will not adequately provide long-term protection and management of biodiversity, so 'ecological networks' and ecological connectivity became a new paradigm to nature conservation in the 21st century (ECNC, 2010).

The EN is a well-known concept, emerged in the past century from the Continuum Naturale concept to 'greenways', up to the post-modern concept of landscape multifunctionality (Magalhães et al., 2007; Selman, 2009) promoted through the European Landscape Convention. Greenways are often used to refer to: a) 'linear open space established along either a natural corridor, or overland along a railroad right-of-way converted to recreational use, a canal, a scenic road, or other route' (Fabos, 1995; Flink and Searns, 1993), b) 'ecological corridor' that connects systems of green and open space in urban areas; c) 'greenway networks' include ecological, recreational and cultural heritage aspects (Fabos, 1995; Magalhães *et al*., 2007).

In this paper, the EN is a spatial concept, considered as a planned network, designed and managed for various purposes (Ahern, 1995) and recognized as a framework of ecological components (Jogman and Pungetti, 2004) which provide physical conditions that are necessary for maintaining or restoring ecological functions, supporting biological and landscape biodiversity and promoting the sustainable use of natural resources (Forman, 1995; Bennett and Wit, 2001; Jongman and Pungetti, 2004).

Furthermore, the idea of EN is embedded in several political strategies and legislative documents at European and international levels (Harfst et al., 2010). The most important policies on EN are: a) the Birds Directive (79/409/EEC, 1979), the Bern Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention, 1979), the Habitats Directive (92/43/EEC, 1992) – Natura 2000; b) Pan-European Biological and Landscape Diversity Strategy (PEBLDS, 1995) – PEEN; c) the Water Framework Directive (Directive 2000/60/EC, WFD 2000); and, d) the latest Biodiversity Strategy in 2011 with Action 6 - Development of a Green Infrastructure Strategy that aims to halt the loss of biodiversity in the EU by 2020 (EC/CIRCABC, 2012).

At the same time, there are several initiatives to prevent landscape fragmentation (Tillmann, 2005) and the Pan-European Ecological Network - PEEN (CE, 1996; Jongman et al., 2011) is one of those, in which the improvement of biodiversity through EN is the main objective.

In these recent European biodiversity policies, "green infrastructure" has become synonymous of "ecological network". Green infrastructure is considered as 'the network of natural and semi-natural areas, features and green spaces in rural and urban, terrestrial, freshwater, coastal and marine areas which together enhance ecosystem health and resilience, contribute to biodiversity

conservation and benefit human populations through the maintenance and enhancement of ecosystem services' (Naumann et al., 2011).

In this paper, the use of the EN expression is due to Portuguese legislation. The EN was established in the national legal regime for territorial management tools in 1999, under Decree-Law nº 380/99, as a tool for landscape planning and management at national, regional and municipal level. In the amendment of the law made by the DL nº 46/2009 (Article 14), EN aims to define areas, values and key systems for environmental protection and the enhancement of urban and rural areas, connecting with another planning tool, the National Ecological Reserve (REN). The REN was created in 1983 under DL nº 321/83, last modified by DL nº 166/2008, and is a biophysical structure that integrates all areas according to their value and ecological sensitivity or exposure, and susceptibility to natural hazards to which should be given special protection. This includes coastal and river areas, aquifer recharge and steep-slope areas for erosion protection.

However, the recent definition is simplistic because, in the 80's, Portuguese law had already established the basis for the EN definition, including National Agricultural Reserve (RAN) under DL nº451/82, last modified by DL nº 73/2009, and the Public Hydric Domain (DPH) under DL nº 468/7 (Magalhães et al., 2007). Also, currently there is the Fundamental Network of Nature Conservation (RFCN), under DL nº 142/2008 which defines a network of conservation areas that integrates these last tools and also includes the National System of Classified Areas (NSCA).

At national level, there is the Program for National Planning Policy (PNPOT) as a strategic tool for territory management. PNPOT, under the Law nº 58/2007, assures the integration of different spatial policies and provides the guidelines to develop the territorial management tools at regional level through regional plans (PROT). PROTs define the regional territorial development strategy, integrating the options established at national level and considering municipal territory development strategies, creating a reference framework for management municipal plans (PMOT). Concerning the EN delimitation in these plans, the national level didn't include any EN delimitation and the regional plan (PROT) establishes the Regional Ecological Network, named as Regional Structure Plan for Environmental Protection and Enhancement (ERPVA), under the Article 51º DL nº46/2009.

Table 1. Relation between EN and the other Portuguese landscape planning tools at national, regional and municipal level

<table>
<tr><th></th><th colspan="2">NATIONAL</th><th>REGIONAL</th><th>MUNICIPAL</th></tr>
<tr><th></th><th>PNPOT</th><th>RFCN</th><th>PROT</th><th>PMOT</th></tr>
<tr><td>EE</td><td>-</td><td>-</td><td>ERPVA</td><td>EEM</td></tr>
<tr><td>DPH</td><td rowspan="5">Natural systems and agro-forestry</td><td rowspan="3">Continuity Areas</td><td rowspan="3">Strategic Guidelines and risk areas</td><td rowspan="3">Restriction Areas</td></tr>
<tr><td>RAN</td></tr>
<tr><td>REN</td></tr>
<tr><td>NSCA</td><td rowspan="2">Nuclear Areas</td><td rowspan="2">Conservation Areas</td><td rowspan="2">Natural Areas</td></tr>
<tr><td>Conservation Areas
Natura 2000, IBAs, Ramsar list, Biosphere and Biogenetic Reserves</td></tr>
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According to this, some gaps in the Portuguese Legal system can be summarized: a) The current legislation does not consider the EN as a single entity, having different names and

representations; b) Criteria and composition of EN is omitted at every scale, emerging therefore, different names, definitions and detailed representations even at the same scale; c) There is no national figure as mandatory and refers to RFCN; d) RFCN is composed by REN, RAN, DPH and NSCA, but in a non-integrated physical and biological base, with particular relevance to nature conservation areas and risk areas; e) the components of RFCN also don't have well-defined criteria. For instance, in the soil protection law (RAN), the soils within urban perimeters (urban and urbanized areas) are excluded from this evaluation, logically compromising the sustainability of urban and peri-urban areas.

The main goal of this paper is to map the EN at national scale. A comparison between our EN delimitation and those made for the plans (PNPOT and PROT) with the purpose of a critical evaluation f these last ones; In order to identify differences between EN delimitation at different scales a comparison was made between National, Regional (Lisbon Metropolitan Area) and Municipal (Lisbon) scales of EN.

Methods

The NEN methodology is composed by two main sub-systems: physical and biological (Figure 1). The physical sub-system includes: a) Water – includes the hydrographic network, water bodies and wetlands. Streams and ridgelines were ranked into four levels according to their watersheds length and area. These elements are integrated in the water legislation (Water Framework Directive) and river basin management plans; b) Land morphology – the inland morphology is characterized by the following ecological situations: wet systems (contiguous areas of water lines), hill tops and slopes; coastal morphology is composed by areas with strong interaction between land and ocean. It includes the beaches, cliffs, geological formations (Quaternary), coastal wetlands (marshes, salt marshes and coastal aquaculture; intertidal zones), transitional waters (estuaries) and marine and coastal waters; c) Soil - with very high and high ecological value constituted of soils with considerable soil depth and the highest rates of fertility, as well soils associated with traditional agro-forestry ecosystems, e.g. Fluvisols, Antrosols, humics Cambisols (FAO and WRB classifications) and aluviosols (Portuguese classification); d) Geology-geomorphology – soil and sub-soil permeability and maximum infiltration areas; e) Climate – cold air corridors and most exposure areas to dominant winds.

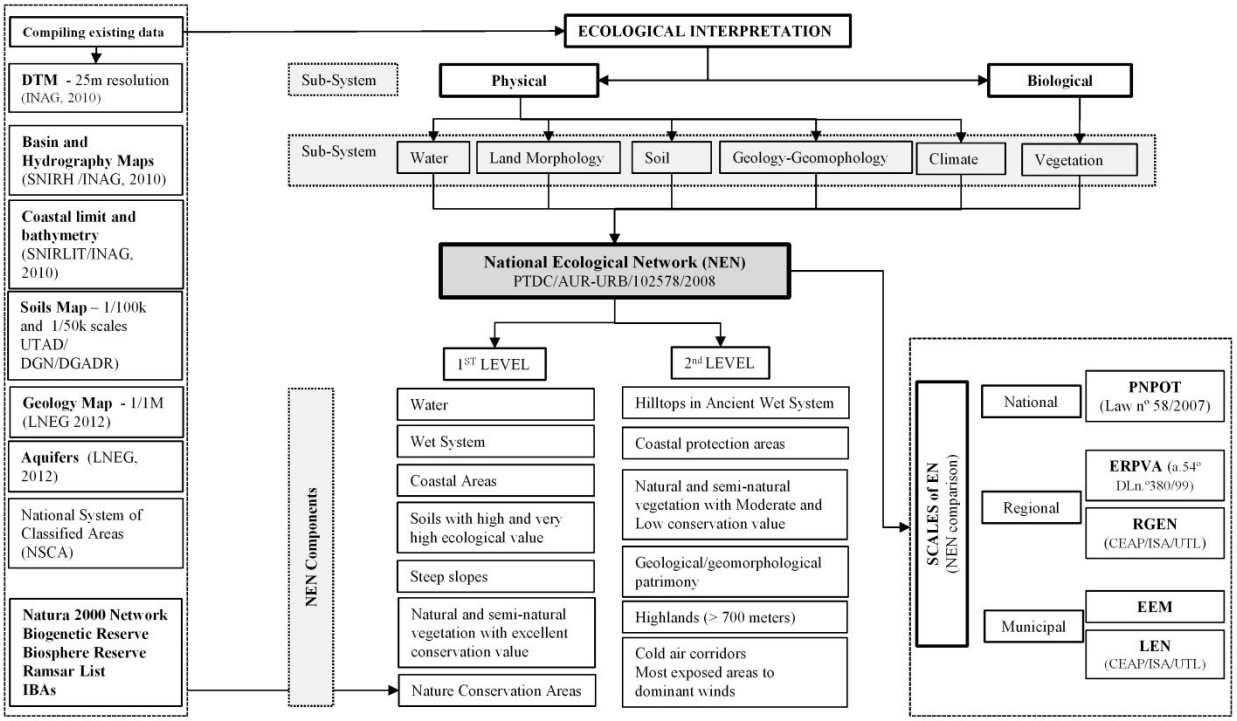


Figure 1. Methodology for NEN mapping

The biological system is composed by: natural and semi-natural vegetation with conservation value, which includes preservation of plant biodiversity (species) and maintenance of the integrity of plant communities (habitats) and vegetation mosaics (complex habitats). This classification considers not only the intrinsic value of the mapped communities, but also the potential occurrence of rare or endangered plants in them.

The integration of all components resulted in a far too extensive area of the country in order to be subjected to significant restrictions in the future. For that reason, it was decided to hierarchize the NEN in two levels, according to the value or degree of ecological sensibility assigned to each component. This paper presents the results of the first level of the NEN as well as its comparison at various scales.

Results

The delimitation of EN at national level (NEN) with the application of the described methodology was implemented through a GIS, using Argis10 software.

The NEN components were systematized and they were given priorities, as presented in Figure 2.a and Figure 3, according the two sub-systems that includes: 1- Water System: water bodies and wet lands; 10 – Wet System (WS): water lines and contiguous areas; 100 - Soil System: with very high and high ecological value; 1000 - Coastal System - beaches, cliffs, geological formations (Quaternary), coastal wetlands, marine, coastal and transitional waters; 10000 – Steep Slopes; 10000 – Vegetation with excellent conservation value. The first level of NEN is composed by these components and nature conservation areas (Figure 5).

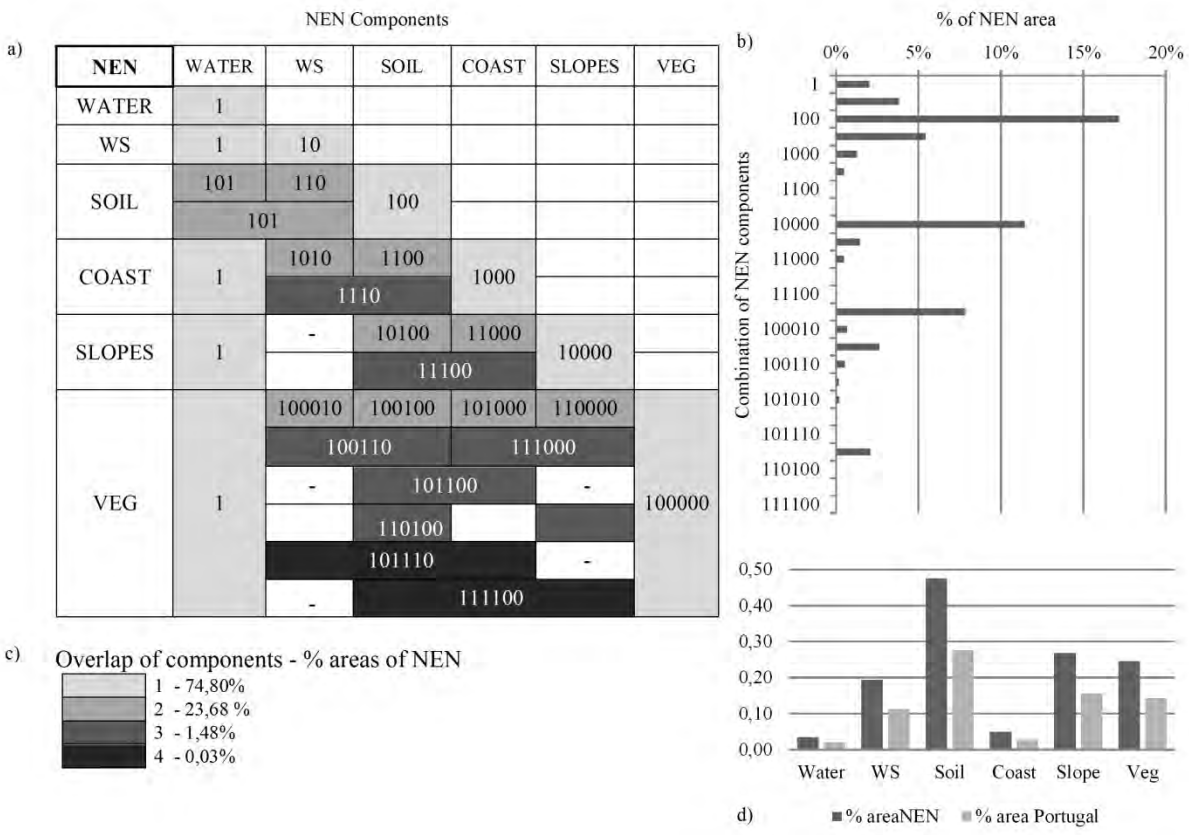


Figure 2. a) Systematization of NEN components; b) NEN components combinations in all NEN area (percentage); c) overlapping components in NEN area (percentage); d) individual components in NEN area and in Portugal area (percentage).

The proposed NEN totalizes 67% of Portugal's area from which 8.5% is composed only by nature conservation areas. Very high and high ecological value soils represent the higher percentage, with 47% of NEN and 27% of country's area. Vegetation and steep slopes represent 25% and 27% of NEN respectively, but only 4% of these components are coincident, representing only 2% of the country. The wet system counts 20% of NEN, 11% of the country, from which 10% are coincident with very high and high ecological value soils (Figure 2.b).

Relatively to NEN as a whole, 74,8 % consists of individual components (Figure 2.c). The dimension of each individual component, relatively to the NEN total area, by decreasing order: soil, slope, vegetation, wet system, coastal areas and water bodies (Fig2.d).

Nature conservation areas (Figure 4) including Natura 2000, IBAs, Ramsar list, Biosphere and Biogenetic Reserves correspond to 25% of the country area but only 16,5 % are coincident with NEN.

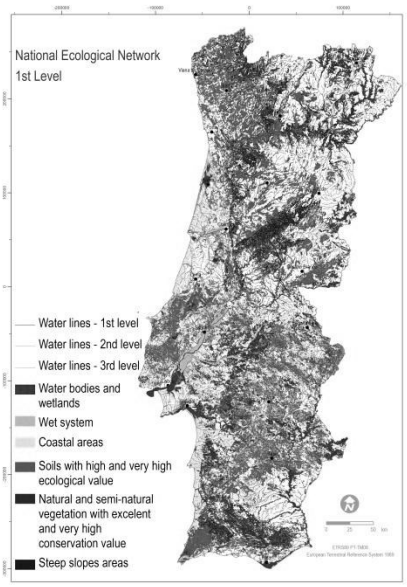


Figure 3. NEN components -1st level

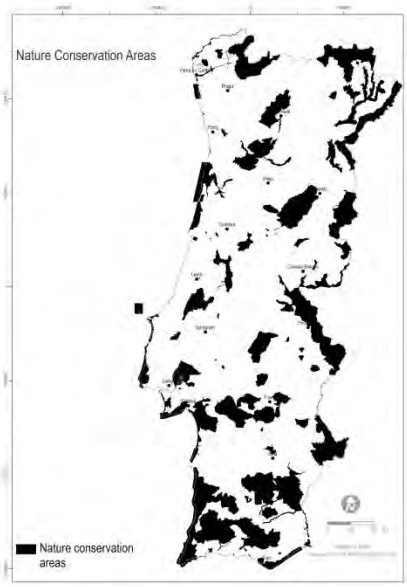


Figure 4. Nature Conservation Areas

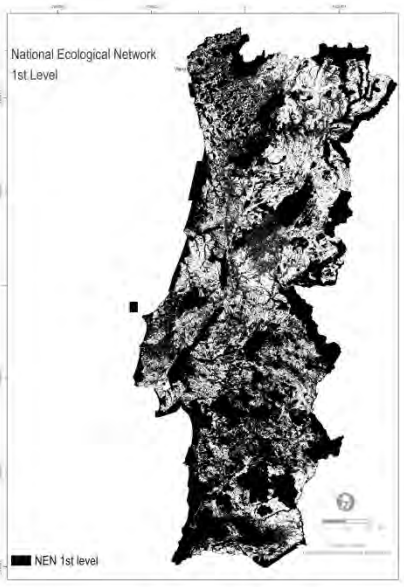


Figure 5. NEN - 1st level

Discussion of results

As mentioned in literature review, the national level of landscape planning tools doesn't include any EN delimitation. The PNPOT only ensures that, at the regional and municipal levels, EN must be consistent and compatible with the ERPVA and Municipal EN provided by plans respectively. PNPOT strongest message about biodiversity enhance is that the three main systems to conservation and sustainable management of natural resources are (Figure 6): water, agricultural and forest land, and nature conservation (DGOTDU, 2007).

However, the considered systems do not constitute a network of natural resources and completely fails the two main objectives that characterize the EN: (1) maintaining the functioning of ecosystems and conservation of species and habitats; and (2) promoting the sustainable use of natural resources in order to reduce the impacts of human activities on biodiversity (Bennett and Wit, 2001). Therefore PNPOT defines: a) 'pine and eucalyptus trees' as agro-forestry systems to be protected. Both of them correspond to intensive monoculture and highly inflammable forest, what is inconsistent with PNPOT's goals, namely with forest fires prevention; and b) 'areas with special agricultural potentiality' refers to the most cultivated areas and not to the soil itself that should be treated as exhaustible resource, a heritage, which by any means should be degraded, regardless of becoming used or not by agriculture, and beyond that is necessary to identify agro-systems that will enable agricultural use (Magalhães, 2001). The used methodology in NEN includes a soil evaluation according with its ecological value which did not exist before.

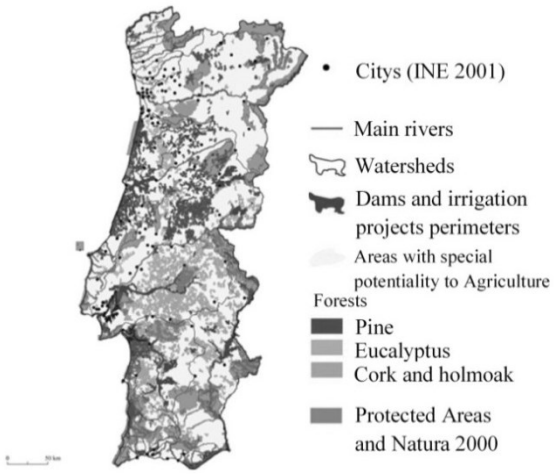


Figure 6. Natural systems and agro-forestry in Portugal (DGOTDU, 2007)

At regional level, the PROT establishes the Regional Ecological Network named as Regional Structure Plan for Environmental Protection and Enhancement (ERPVA).The selected example for this analysis is the Lisbon Metropolitan Area ERPVA (Figure 7). ERPVA comprises a hierarchical network composed of areas and ecological corridors (primary, secondary and complementary networks) linked to each other by protected areas. Nevertheless these areas selection were based only on land use criteria in a specific period and not in the ecological suitability to human activities. The major review is that these networks are schematically represented and we believe that it´s possible to detail the EN components at all scales, as represented in Figures 8 and 10, with the comparison of NEN with regional and municipal EN (RGEN and LEN) proposed by CEAP/ISA/UTL.

For Lisbon Metropolitan Area, NEN corresponds to 53,21% of this area and 92,55% of this NEN are coincident with the RGEN. However RGEN is more accurate and has 16,85 % more area than NEN, due to a more precise land use data, namely vegetation inventory and the hydrographic system that includes a lower hierarchy of water lines.

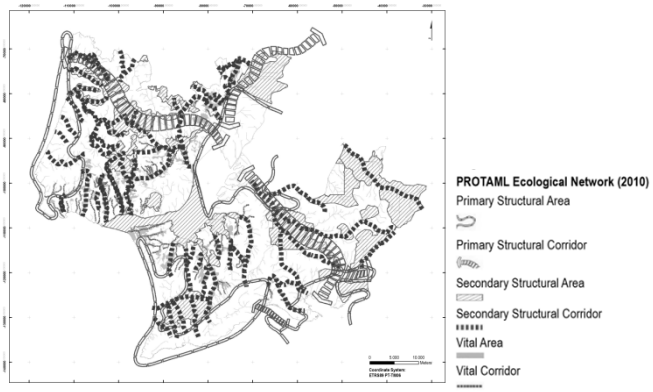


Figure 7. ERPVA of Lisbon Metropolitan Area

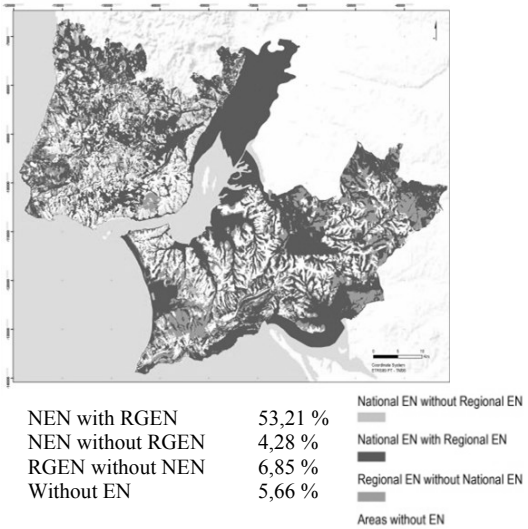


Figure 8. Comparison between NEN and RGEN (CEAP/ISA/UTL)

Legally, municipalities must have an EN mapped in their municipal plan (PDM), but there are no established criteria on how to define and develop it. Figures 9 and 10 represent the proposed EN for Lisbon's municipality (CEAP/ISA/UTL), according to the same methodology of NEN. However Lisbon's EN (LEN) included green spaces in urban areas, such as parks, permeable open spaces and urban elements hosting biodiversity, this justifies the difference between NEN and LEN area (Figure 10), more 43,8% area in LEN.

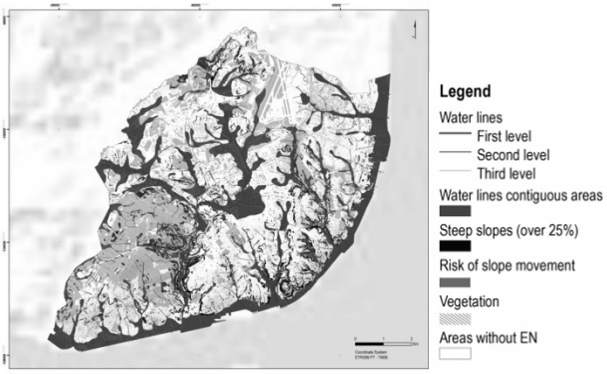
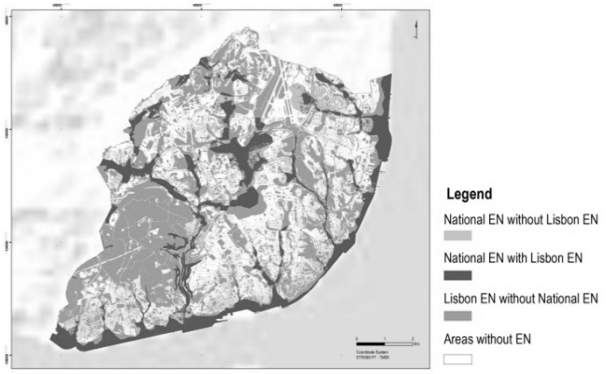


Figure 9. EN for Lisbon municipality (CEAP/ISA/UTL)



NEN with LEN	15,96%
NEN without LEN	3,14%
LEN without NEN	43,87%
Without EN	37,03%

Figure 10. Comparison between NEN and LEN

Conclusions

The first conclusion is that is possible to delimitate the EN at national level with an accuracy that allows its transposition to the scale of 1/25.000. This finding contradicts what has been done in Portugal, particularly in the PNPOT and in the PROTs, and underpin the European recommendations about green infrastructures.

Regarding its dimensions, the NEN corresponds approximately to 58% of Portugal's total area. On the other hand, the nature conservation areas (Natura 2000, IBAs, Ramsar list, Biosphere and Biogenetic Reserves) represents 25% of the country, of which only 16,5% matches the NEN. The difference between these two values is explained by the fact of the NEN is including the physical sub-system of the landscape, rather than focusing only on the biotic systems, as do the nature conservation areas.

Regarding NEN components overlapping, it was verified that 14% of the vegetation areas with conservation value do not overlap to other components of the NEN, corresponding mostly to oak forests (*Quercus suber e Quercus rotundifolia*) of the South of Portugal, particularly adapted to the extreme conditions of climate, soil and water availability. Moreover, 10% of the NEN corresponds to the overlap of soils and wet system, which matches aluviosoils and fluvisoils.

Finally, 75% of the physical sub-system areas (water, wet system, soils, coastal areas and slopes) do not host relevant vegetation and only 9% of the physical sub-system matches the vegetation with conservation value. These numbers allow concluding that there is, in fact, a biological sub-system dissociated of the physical sub-system of the landscape, so the protection given the last years to the biotic system is insufficient to ensure the ecological balance of the landscape. The

concept of Ecological Network in this paper is widely justifiable and should be considered as a reference to future law modifications.

Acknowledgements

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