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Review paper

Exploring forest infrastructures equipment through multivariate analysis: complementarities, gaps and overlaps in the Mediterranean basin

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Abstract - The countries of the Mediterranean basin face several challenges regarding the sustainability of forest ecosystems and the delivery of crucial goods and services that they provide in a context of rapid global changes. Advancing scientific knowledge and fostering innovation is essential to ensure the sustainable management of Mediterranean forests and maximize the potential role of their unique goods and services in building a knowledge-based bio-economy in the region. In this context, the European project FORESTERRA ("Enhancing FOrest RESearch in the MediTERRAnean through improved coordination and integration") aims at reinforcing the scientific cooperation on Mediterranean forests through an ambitious transnational framework in order to reduce the existing research fragmentation and maximize the effectiveness of forest research activities. Within the FORESTERRA project framework, this work analyzed the infrastructures equipment of the Mediterranean countries belonging to the project Consortium. According to the European Commission, research infrastructures are facilities, resources and services that are used by the scientific communities to conduct research and foster innovation. To the best of our knowledge, the equipment and availability of infrastructures, in terms of experimental sites, research facilities and databases, have only rarely been explored. The aim of this paper was hence to identify complementarities, gaps and overlaps among the different forest research institutions in order to create a scientific network, optimize the resources and trigger collaborations.

Keywords - FORESTERRA, infrastructures, multidimensional scaling, Mediterranean countries

Introduction

The countries of the Mediterranean basin, as well as those of other geographical areas with a Mediterranean climate, are facing problems regarding the sustainability of forest ecosystems and the provision of essential goods and services, in a context of rapid global change (Lindner 2010, Lafortezza et al. 2013).

The Mediterranean forest regions cover areas typically characterized by high intrinsic diversity in several inter-related aspects: ecological, environmental, cultural, economic, social and historical (Scarascia Mugnozza et al. 2000, Fabbio et al. 2003). For this reason it is important to advance scientific knowledge and promote innovation, which is essential to ensure the sustainable management of Mediterranean forests, maximizing the potential role of their goods and services in building a knowledge-based bio-economy of the region (Croitoru 2007, Merlo and Rojas 2000). The FP7 European Project FORESTERRA ("Enhancing FOrest RESearch in the MediTERRAnean through improved coordination and integration") has the objective to strengthen scientific cooperation on Mediterranean forest research through the integration and harmonization of research, infrastructure and existing databases through an ambitious transnational framework to reduce the fragmentation of existing forest research and maximize its impact (http://www.foresterra.eu/).

There are a number of regional organizations and research projects that collect data and compile information relevant to Mediterranean forests and related issues, such as FAO Silva Mediterranea Committee, AIMF, Biodiversity International, Blue Plan, CIHEAM, CIRCE of INGV, CMA and SEL of CRA, EFIMED, FOREST EUROPE, JRC (in particular EFFIS for forest fires), MMFN, OFME, UNECE, URFM of INRA, WWF, LFCC process, etc. (FAO 2011). Yet, each of these entities looks at this issue from different perspectives by collecting data in response to specific questions and needs or with a geographic focus which only embeds a part of the

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Mediterranean rim. The resulting evidence is that forest research in the Mediterranean is poorly exchanged and unequally developed (Saket 2002). In fact, while forest research is well developed in some European countries like France, Spain and Italy, its development is significantly lower in other countries where few resources are allocated to forest research (Palahi et al. 2008, Scarascia Mugnozza et al. 2000). Such gaps are particularly evident when dealing with infrastructures. In this perspective, the identification of Mediterranean countries whose level of forest research development and infrastructure equipment is different provides an opportunity to enhance the general level and to improve the quality of forest research in the area as a whole (Turner et al. 2003).

To the best of our knowledge, the equipment and availability of infrastructures, in terms of experimental sites, research facilities and databases, have only rarely been explored. Other scientific disciplines tried to analyze such issue (e.g. Kennedy et al. 2008), but no attention has been paid to forest research infrastructures so far.

According to the European Commission, research infrastructures are facilities, resources and services that are used by the scientific communities to conduct research and foster innovation (http://eurofed.stis.belspo.be/eurofed.asp?id=300;100;400&lang=en). They include: major scientific equipment (or sets of instruments); knowledge-based resources such as collections, archives or scientific data; e-infrastructures, such as data and computing systems and communication networks; and any other infrastructure of a unique nature essential to achieve excellence in research and innovation.

Research infrastructures play an increasing role in the advancement of knowledge and technology and of their exploitation (Archibugi and Pietrobelli 2003). Research infrastructures help structuring the scientific community and play a key role in the construction of an efficient research and innovation environment by offering high quality research services to users from different countries, by attracting young people to science and by networking facilities towards open, interconnected, data-driven and computer-intensive science and engineering.

In this perspective, within the framework of FORESTERRA project, the aim of this paper is twofold: (i) making a survey of the types of forest infrastructures available across the Mediterranean basin and (ii) identifying complementarities, overlaps and gaps among the different Mediterranean countries in terms of forest infrastructures, in order to create a scientific network, optimize the resources and trigger future collaborations.

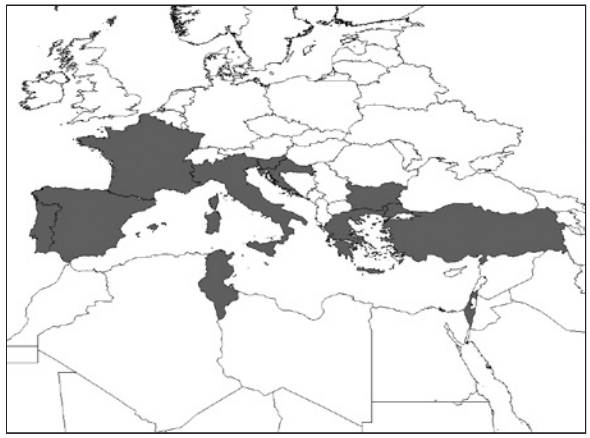

Figure 1 - Location of the FORESTERRA countries analyzed.

Study area

The Mediterranean basin extends for 3,800 km from east to west, starting from the head end of Portugal to the shores of Lebanon, and about 1,000 km from north to south, from Italy to Morocco and Libya. In the European Union, seven Member States are included in the Mediterranean region, some only partially (France, Portugal, Italy, Spain), wholly others (Greece, Malta, Cyprus).

All areas of the Mediterranean region are home to site-specific wild animals and plants, with a large number of species not detectable anywhere else in the world. The rate of endemism is exceptionally high: over half of the 25,000 flowering plants identified to date in the region, equivalent to about 10% of all known plants on Earth, is made up of endemic species. Mediterranean is thus among the areas of the world with the highest biodiversity (Mittermeier et al. 2004, Underwood et al. 2009).

Data

The FORESTERRA questionnaires on infrastructures were generated by reviewing and amending similar initiatives carried out previously (e.g. ERANET-ARIMNET and JPI-FACCE). A Mediterranean forestry research framework database was hence generated from the information gathered from the questionnaires received from eleven Mediterranean countries of the FORESTERRA Consortium: Spain, France, Italy, Turkey, Portugal, Tunisia, Bulgaria, Slovenia, Croatia and Greece (Fig. 1).

We detected nine-teen types of infrastructures (Tab. 1) covering the forest research activities of the FORESTERRA countries analyzed. We excluded from further analysis the infrastructures common to all countries: Experimental plantation & Forest research site for long-term monitoring; Forest Genetics and Biotechnology Lab; Forest Nursery, Rhizo/

Table 1 - List of forest infrastructures recorded through the questionnaires.

	INFRASTRUCTURES
1.	Arboretum, Forest genetic trial, Seed bank & Seed lab
2.	Biomass, Economics & Wood Technology labs
3.	Botanical garden & Botany lab
4.	Carbon flux towers
5.	Eco-physiology lab
6.	Environmental, GIS and Forest Geomatics labs
7.	Experimental plantation & Forest research site for long-term monitoring
8.	Fire ecology labs
9.	Forest Biochemistry lab
10.	Forest Genetics and Biotechnology lab
11.	Forest Hydrology lab
12.	Forest Nursery, Rhizo/Phytotrons & Micropropagation lab
13.	Forest Protection lab (entomology and pathology)
14.	Meteorological station, lab & field equipments for climate change studies
15.	Mobile Lab Unit
16.	Silviculture & Forest biometry lab
17.	Soil lab
18.	Stable isotopes & Chemistry labs
19.	Wood harvesting, Mechanization, Trasportation & Ergonomics lab

Phytotrons & Micropropagation lab; Meteorological station, lab & field equipments for climate change studies; Stable isotopes & Chemistry labs.

Methodology

A data matrix X was created having dimension i, j where i is the number of different types of research infrastructure while j is the number of considered countries. The matrix element x_{ij} was set up to one if the j-th country owns the i-th infrastructure, or to zero when such infrastructure is not present in the country.

The row vector x_i represents the distribution of the i-th infrastructure i within countries. The column vector x_j represents the infrastructural endowment of the country. A country owning all (none) infrastructure would have a vector x_j having all "1" (or "0").

The analysis was carried out in three steps. In the first step we analyzed the simple ordering of countries by number of infrastructures owned and of infrastructures by number of countries in which it is distributed. Then, we analyzed the relationships between pairs of countries in terms of mutual complementarities of infrastructures. In the last step we made use of multidimensional scaling technique to determines groups of countries similar by infrastructural equipment (Salvati and Zitti 2009). This allows to highlight common patterns of specialization.

The simple ordering of countries and infrastructures (step 1) was obtained by respectively summing the elements of the correspondent column or row vectors:

$$C_j = {}_i\sum x_{ij} \qquad R_i = {}_j\sum x_{ij}$$

In the step 2, we created the square matrixes I having dimension jxj in which each element represents a relationship between a pair of countries. Such relationship is expressed by the mean of a complementarity index between the two countries $j1$ e $j2$. We created three matrixes that correspond to three different complementarity indices: a general complementarity index I^1, a specific complementarity index I^2 and a relative specific complementarity index I^3. The general complementarity index I^1 represents the number of different infrastructures that are owned by one and only one of the two countries divided by the total number of different infrastructures I:

$$I^1_{j1,j2} = [{}_i\sum |x_{ij1} - x_{ij2}|] \,/\, I$$

It takes maximum value 1 when the two countries are perfectly complementary without overlapping; it takes the minimum value of 0 when the countries own exactly the same kind of infrastructures. This index is symmetric (i.e. the value does not change inverting the two countries $j1$ and $j2$) and thus the matrix I^1 is symmetric. We can interpret this index as the overall result of a partnership between the two countries.

The specific complementarity index I^2 represents the number of infrastructures missing in the country J^1 and owned by the country J^2, divided by the total number of different infrastructures J:

$$I^2_{j1\,j2} = [{}_i\sum (1-x_{ij1})\, x_{ij2}] \,/\, I$$

It takes the maximum value 1 when the country j^1 has no infrastructure while country J^2 has all the kind of infrastructures considered; it assumes the minimum value 0 when the countries have the same kind of infrastructures. It can be considered as a proxy for the effect of the partnership between the two countries from the point of view of country $j1$.

The relative specific complementarity index I^3 represents the number of infrastructure missing in the country J^1 and owned by the country J^2, divided by the number of infrastructures missing to the country J^1:

$$I^3_{j1,j2} = [{}_i\sum (1-x_{ij1})\, x_{ij2}] \,/\, [{}_i\sum (1-x_{ij1})]$$

It takes the maximum value 1 when the country J^2 has all the infrastructures missing to the country J^1. It takes the minimum value 0 when the country J^2 has none of the infrastructures missing in country J^1. It can be considered as the relative effect of the partnership between the two countries from the point of view of country J^1.

Finally, to determine a two-dimensional clas-

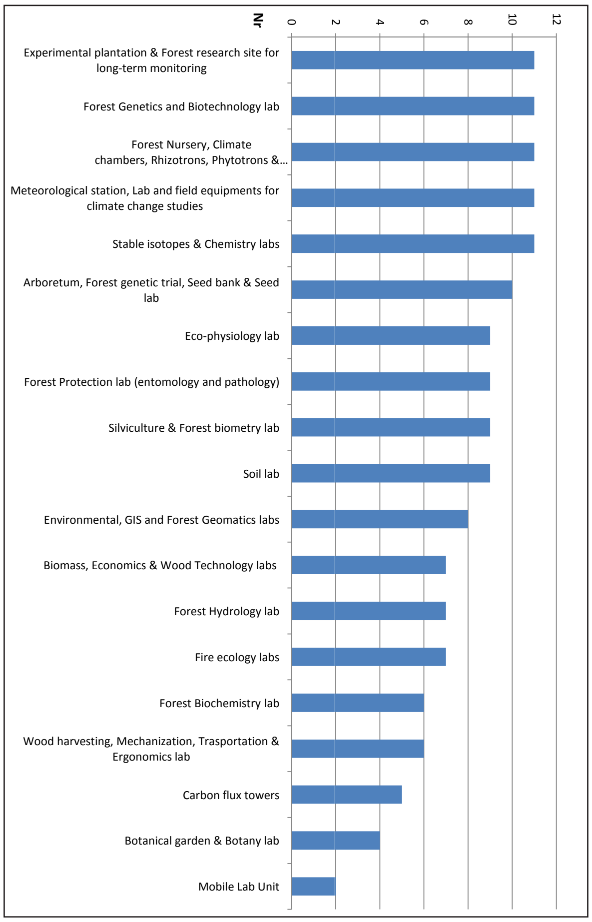

Figure 2 - Frequency graph of the infrastructures belonging to the forest research institutes of the FORESTERRA countries.

sification of the infrastructural systems among the different countries, we performed a Multi-Dimensional Scaling (MDS) analysis. MDS is a means of visualizing the level of similarity of individual cases of a dataset. It refers to a set of related ordination techniques used in information visualization, in particular to display the information contained in a distance matrix. An MDS algorithm aims to place each object in N-dimensional space such that the between-object distances are preserved as well as possible. Each object is then assigned coordinates in each of the N dimensions. The number of dimensions of an MDS plot N can exceed 2 and is specified a priori. Choosing N=2 optimizes the object locations for a two-dimensional scatterplot (Borg and Groenen 2005, Honarkhah and Caers 2010).

Starting from the matrix X, we set up the square matrix of scalar products $P=X^TX$ having dimension JxJ (which corresponds to the matrix of the indices I^1 multiplied by J). We decided to apply an Euclidean metric to the matrix of distances between countries.

We applied to this matrix the dimensional reduction by finding sequentially the vectors that minimize a loss function of the distances from the points d.

Results and Discussion

The analysis allowed to identify the geographical distribution of the forest infrastructures across Mediterranean countries, identifying the most and the less common infrastructure (Fig. 2) and the most and less endowed country (Tab. 2).

Table 2 - Ranking of countries by endowment of infrastructures.

FORESTERRA countries	Nr. of infrastructures
Italy	18
Turkey	17
Spain	17
France	17
Greece	16
Slovenia	15
Israel	14
Portugal	13
Croatia	11
Tunisia	9
Bulgaria	6

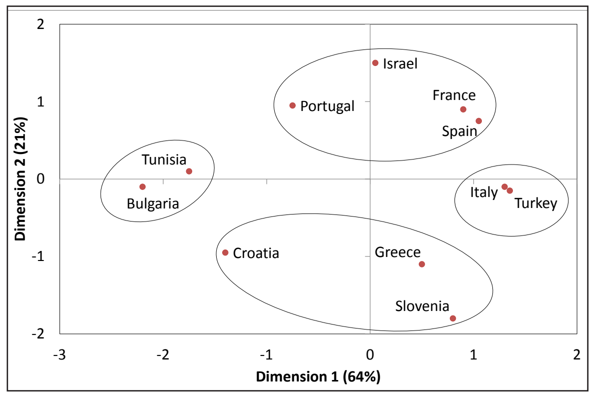

Figure 3 - Scatter plot of the MDS analysis.

The MDS analysis in two dimensions had a data fitting of about 85% (depending on Mardia's Fit Measure) with 64% in the first dimension and 21% of the second, respectively (Fig. 3). The first dimension summarizes the infrastructure that are substantially more common (greater weight to more variables present). Essentially, it repeats the ranking by number of infrastructure. While Turkey and Italy are almost overlapping and are well represented by the first dimension, the second dimension shows two models of specification in the countries immediately following in the list: on the one hand, Slovenia, Greece and Croatia, on the other Israel, Portugal , France and Spain. Bulgaria and Tunisia are confirmed to be poorly endowed by general infrastructure, and not equipped of specific infrastructure. The intermediate position on this dimension of the countries most endowed is compatible with the presence in these countries of both types of specializations.

Looking at the original data (not shown here), it is possible to identify the specific infrastructures that characterize the groups of countries classified by the second dimension: Carbon Flux Towers; Forest Biochemistry lab; Forest Nursery, Rhizo/Phytotrons & Micropropagation lab; Stable isotopes & Chemistry labs, for the countries at the top of the figure; Botanical garden & Botany lab; Eco-physiology lab; Arboretum, Forest genetic trial, Seed

Table 3 - Matrix of indices of general complementarity (number of complementary infrastructures on total infrastructure).

	Italy	Turkey	Spain	France	Greece	Slovenia	Israel	Portugal	Croatia	Tunisia
Turkey	15%	-								
Spain	20%	15%	-							
France	30%	25%	10%	-						
Greece	40%	25%	40%	40%	-					
Slovenia	35%	30%	45%	55%	45%	-				
Israel	40%	35%	20%	20%	60%	65%	-			
Portugal	45%	40%	35%	35%	55%	60%	25%	-		
Croatia	65%	70%	55%	55%	55%	50%	55%	50%	-	
Tunisia	65%	60%	55%	55%	55%	60%	45%	20%	40%	-
Bulgaria	80%	75%	70%	70%	60%	75%	50%	35%	35%	25%

Table 4 - Matrix of indices of specific complementarity (number of infrastructures obtained in the partnership by the row country on total infrastructure).

	Italy	Turkey	Spain	France	Greece	Slovenia	Israel	Portugal	Croatia	Tunisia	Bulgaria
Italy	-	5%	10%	5%	10%	5%	5%	0%	5%	0%	0%
Turkey	10%	-	10%	5%	5%	5%	5%	0%	10%	0%	0%
Spain	20%	15%	-	5%	15%	20%	0%	0%	5%	0%	0%
France	15%	10%	5%	-	15%	15%	0%	0%	5%	0%	0%
Greece	30%	20%	25%	25%	-	20%	25%	15%	10%	5%	0%
Slovenia	30%	25%	35%	30%	25%	-	30%	20%	10%	10%	10%
Israel	35%	30%	20%	20%	35%	35%	-	5%	15%	5%	0%
Portugal	45%	40%	35%	35%	40%	40%	20%	-	20%	0%	0%
Croatia	60%	60%	50%	50%	45%	40%	40%	30%	-	15%	5%
Tunisia	65%	60%	55%	55%	50%	50%	40%	20%	25%	-	5%
Bulgaria	80%	75%	70%	70%	60%	65%	50%	35%	30%	20%	-

Table 5 - Matrix of indices of relative specific complementarity (number of infrastructures obtained in the partnership by the row country on total infrastructure missing to the same country).

	Italy	Turkey	Spain	France	Greece	Slovenia	Israel	Portugal	Croatia	Tunisia	Bulgaria
Italy	-	50%	100%	50%	100%	50%	50%	0%	50%	0%	0%
Turkey	67%	-	67%	33%	33%	33%	33%	0%	67%	0%	0%
Spain	100%	75%	-	25%	75%	100%	0%	0%	25%	0%	0%
France	75%	50%	25%	-	75%	75%	0%	0%	25%	0%	0%
Greece	100%	67%	83%	83%	-	67%	83%	50%	33%	17%	0%
Slovenia	86%	71%	100%	86%	71%	-	86%	57%	29%	29%	29%
Israel	88%	75%	50%	50%	88%	88%	-	13%	38%	13%	0%
Portugal	82%	73%	64%	64%	73%	73%	36%	-	36%	0%	0%
Croatia	92%	92%	77%	77%	69%	62%	62%	46%	-	23%	8%
Tunisia	87%	80%	73%	73%	67%	67%	53%	27%	33%	-	7%
Bulgaria	89%	83%	78%	78%	67%	72%	56%	39%	33%	22%	-

bank & Seed lab for the countries in the lower part.

In conclusion, we can classify the forest research infrastructures equipment of the analyzed countries in four groups:

1) countries characterized by the presence of nearly all the infrastructure, consisting on Italy and Turkey;
2) countries with only a few general infrastructure (Tunisia and Bulgaria);
3) a "West Europe and Israel" model with large occurrence of Carbon Flux Towers, Forest Biochemistry lab, Stable isotopes and Microscopy Lab & Chemistry labs, composed of Israel, which is the most characteristic country of the group, and three Western Mediterranean countries (Portugal, France and Spain);
4) a "Balkan" model with large occurrence of Botanical garden & Botany lab, Eco-physiology lab and Arboretum, Forest genetic trial, Seed bank & Seed lab, composed of Slovenia, Greece and Croatia (which has less infrastructure but more specific than group 2).

Consequently, as also suggested by the complementarity indices analysis (Tab. 3, Tab. 4 and Tab. 5), while for the group 2 is necessary to develop agreements with most endowed countries (group 1 but also some in groups 3 and 4), bilateral partnerships could be fruitful in particular for groups 3 and 4 considering the different pattern of specialization. The unique bilateral partnership that allows full coverage are those integrating Italy (which also has the specific infrastructure of the two specialized models) with France or Greece. Agreements among more than two countries should include members of all the four groups.

Conclusions

In a framework of scientific and technical forest research, this study may help to: (i) foster coordination and integration of forest research activities at European level; (ii) endorse the multidisciplinary approach to address new research challenges through closer cooperation between different research fields (silviculture, ecology, physiology, climatology, molecular biology, pathology, wood technology, etc.); (iii) increase scientific and technical excellence; (iv) make easier the access to complementary research facilities and expertise between national and international institutions, optimizing the use of technical resources; (v) create support studies on the multifunctionality of the European forests.

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References

Archibugi D., Pietrobelli C. 2003 - *The globalisation of technology and its implications for developing countries. Windows of opportunity or further burden?* Technological Forecasting & Social Change 70: 861–883.

Borg I., Groenen P. 2005 - *Modern Multidimensional Scaling: theory and applications* (2nd ed.). New York: Springer-Verlag, 207–212. ISBN 0-387-94845-7

Croitoru L. 2007 - *How much are Mediterranean forest worth?* Forest Policy and Economics 9: 536-545.

Fabbio G., Merlo M., Tosi V. 2003 - *Silvicultural management in maintaining biodiversity and resistance of forest in Europe – the Mediterranean region.* Journal of Environmental Management 67: 67-76.

FAO 2011 - *State of Mediterranean Forest (SoMF)*. FAO Rome, Italy Press: 9-11

Honarkhah M., Caers J. 2010 - *Stochastic Simulation of Patterns Using Distance-Based Pattern Modeling.* Mathematical Geosciences 42: 487–517.

Kennedy A., Khoja T.A.M., Abou-Zeid A.H., Ghannem H., IJsselmuiden C. 2008 - *National health research system mapping in 10 Eastern Mediterranean countries.* La Revue de Santé de la Méditerranée orientale 14: 502-517.

Lafortezza R., Sanesi G., Chen J. 2013 - *Large-scale effects of forest management in Mediterranean landscapes of Europe.* iForest 6: 331-335.

Lindner M., Maroschek M., Netherer S., Kremer A., Barbati A., Garcia-Gonzalo J., Seid R., Delzon S., Corona P., Kolstroma M., Lexer M.J., Marchetti M. 2010 - *Climate change impacts, adaptive capacity, and vulnerability of European forest ecosystem.* Forest Ecology and Management 259: 698-709

Merlo M., Rojas Briales E. 2000 - *Public goods and externalities linked to Mediterranean forests: economic nature and policy.* Land Use Policy 17: 197-208

Mittermeier R.A., Gil P.R., Hoffmann M., Pilgrim J., Brooks T., Mittermeier C.G., Lamoreux J., Da Fonseca G.A.B. 2004 - *Hotspots Revisited: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions.* University of Chicago Press for Conservation International.

Palahi M., Mavsar R., Gracia C., Birot Y. 2008 - *Mediterranean forests under focus.* International Forestry Review 10: 676-688.

Saket M. 2002 - *Gaps in national-level information on forests and trees in developing countries.* Unasylva 53: 24-27.

Salvati L., Zitti M. 2009 - *The environmental 'risky' region: identifying land degradation processes through integration of socio-economic and ecological indicators in a multivariate regionalization model.* Environmental Management 44: 888-899.

Scarascia-Mugnozza G., Oswald H., Piussi P., Radoglou K. 2000 - *Forests of the Mediterranean region: gaps in knowledge and research needs.* Forest Ecology and Management 132: 97–109.

Turner K., Paavola J., Cooper P., Farber S., Jessamy V., Georgiou S. 2003- *Valuing nature: lessons learned and future research directions.* Ecological Economics 46: 493– 510.

Underwood E. C., Viers J. H., Klausmeyer K. R., Cox R. L., Shaw M. R. 2009 - *Threats and biodiversity in the Mediterranean biome.* Diversity and Distributions 15: 188–197.