# Linking the forest research in the Mediterranean area: A framework to improve research capacities and cooperation

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## ABSTRACT

Building research capacity in forest science has been recognized internationally as important in order to produce a sound evidence basis for decision-making in policy and practice, even if there is currently little evidence on how to measure and consequently spread progress and innovations resulting from forest research, especially in a fragmented region such as the Mediterranean.

The paper aims at establishing a framework from 79 institutions undertaking forest research across thirteen Mediterranean countries for measuring their research capacities and the potential they reached to disseminate results and innovations in forest research. The methodology adopted makes use of common indicators thereby allowing comparisons across countries as regards the following: (i) research lines performed in forest research, (ii) budget generated by forest projects, (iii) overall full budget spent for forest research, (iv) number of forest projects implemented, (v) number of total researchers, permanent staff and non-permanent staff deployed in forest research, and (vi) ISI papers published in forest subjects.

Forest research capacities have tentatively been clustered to find similarities or dissimilarities across countries, in order to identify possible partnerships to be reached and to highlight causal indicators that affected the clustering.

The paper findings contribute to address how capacity for forest research in the Mediterranean area is developed and how to measure and evaluate the performances of research and innovation systems. They provided further contributions to existing debates in the literature in order to foster research collaboration in the forest sector, knowledge mobilization, innovation and proposals/policies for a common research framework in the European forest sector.

## 1. Introduction

Mediterranean forests and woodlands, which cover about 9% of the Mediterranean region's land area, require special attention because of the following: (i) they constitute a unique world natural heritage in terms of biological diversity, hosting around 25,000 species of vascular plants (50% are endemic species) and a high degree of tree richness and endemism with extraordinary genetic diversity, (ii) their conservation and appropriate management have crucial impacts on the sustainability of the region's most strategic water resource, (iii) they provide highly appreciated and unique non-wood products and non-market services, and (iv) their future (as being in a transitional zone) is seriously endangered by climate change (MFRA, 2009; Palahí et al., 2008; Scarascia Mugnozza et al., 2000). Rapid and abrupt land-use changes, mainly due to development pressures, urban sprawl and habitat fragmentation resulting from transport infrastructures, resource overexploitation and pollution, are few of the main factors impacting upon Mediterranean forests and driving their degradation. Advancing and integrating forest research are an essential prerequisite to create the basis for innovation and to provide the scientific expertise to develop efficient cross-cutting policies and new forest management models based on the key-role of forests. Much of recent literature on this topic suggests that the key to addressing this challenge is to identify ways to improve engagement between scientists, industry, communities and decision-makers through communication and collaboration, ultimately making science more democratic, credible, legitimate and therefore relevant to public policy processes (Hickey, 2013). On the other

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hand, research institutions are somewhat alone in finding the right way forward, as ministerial governing bodies tend to be tied up in existing research topics, therefore science often does not succeed in providing the knowledge needed in due time (Hickey, 2013; Stevanov et al., 2013; McKinley et al., 2012; Klenk and Hickey, 2013; von Teuffel, 2011). The existing debates about the overall role of science in policy making focus on the following: i) improving the quality of interactions between scientists and decision-makers within governments; ii) improving the synthesis and communication of science to society; iii) improving the transparency of scientific results offered to decision-making processes; and iv) increasing the strategic planning affecting science procurement and funding (Hickey, 2013 and references cited therein). The abovementioned studies also highlight that scientific requirements of peer-review publications are often in contrast with practice-oriented needs of practitioners. They investigated the transfer of scientific knowledge and discuss the institutional design of research organizations leading to application in practice. In this regard, Stevanov et al. (2013) evaluated how the provision of science-based policy advice met the demands of policy actors in 148 projects conducted between Serbia and Croatia. They identified useful methods to improve research evaluation by investigating besides the typical measures of research outputs (i.e., peer-review), the key-role that 'in-house' government research plays in producing science-based policy advice on forests, which is bound to scientific, political, and economic expectations. Similarly, McKinley et al. (2012) supported citizen science and participatory research approaches, which bring to varying extents resource managers, decision makers, and the public into the research process. Petrokofsky et al. (2013) proposed a bibliometric study for examining the existing knowledge base in relation to ten specific priority questions relevant to forestry research (T10Q) addressed to 481 individuals with a professional interest in forestry (i.e., researchers, stakeholders, policymakers and nongovernmental organization). Klenk and Wyatt (2013) and Klenk and Hickey (2013) calibrated a model embracing knowledge production and mobilization to foster forest research innovation and meet the needs of the Canadian forest sector. They separated research conducted by universities from that carried out by research institutes, concluding that whereas university-based research is governed by incentive structures of academia and funding councils (i.e., peer-reviewed papers, presentations at conferences, highly trained personnel), research institutes are ruled by the needs of their partners and thus reflect a reflexive problem-solving and innovation orientation. At the same time, the forest sector is increasingly under pressure and its political marginalization is progressive. This is due to few forest research institutions being successful in creating viable forest research frameworks to coordinate research on complex issues, to involve collaborative teams of researchers and partner organizations from different geographic areas, and to synergize their forest research capacities to pursue a common objective. At this purpose, the European Forest Institute (EFI) is developing its Regional Offices as the main instrument for pan-European networking (Päivinen, 2011).

In this context, we conducted an inventory of existing forest research activities and capacities among thirteen Mediterranean countries in order to establish a framework to measure performances, capacities and potential reached in disseminating results and innovations in forest research. In order to determine the effectiveness and the potential reached by the Mediterranean forest research framework, we used representative international research performance indicators related to budget, productivity, innovation and dissemination as well as to internationally accepted research results, personnel deployed and research lines (Meek and van der Lee, 2005; Sizer, 1990; Rudd, 1988). Based on data obtained, the main aim of the study was to perform a cluster analysis to identify similarities and/or dissimilarities in forest research capacities across surveyed countries in order to identify potential partnerships to achieve. Consistently, we would expect countries showing similarities to be grouped in the same cluster and similar research systems in terms of budget, personnel, publications and innovations to lead to potential collaborations and enhanced research potential.

Conversely, countries that showed dissimilarities with each other would be expected to be split across different clusters. Moreover, relationship analyses among indicators were performed to address questions relating to causal indicators that affected the country clustering. The study also aims at providing further contributions to existing literature on research performance and research cooperation in the forest sector.

### 1.1. Analytical framework

Mediterranean forest research includes many researchers and numerous institutions from more than 20 different countries of the region; however, it is highly fragmented while forest research programs, competencies and capacities have often been locally managed (Scarascia Mugnozza et al., 2012). There is a huge diversity of stakeholders, in terms of ways of action, dimension, interaction with forest, or forestry related skills. This could be an obstacle for developing a research strategy for a sustainable and competitive forest sector. Indeed, efforts to strengthen forest research collaborations and capacities in Mediterranean countries have with some exceptions, been ineffective. Part of the explanation for this disappointing performance may be that few studies have attempted to assess the various factors that determine research capacity and performance in the forest sector. Another part of the explanation could be that the process of building a framework for the Mediterranean forest research is seldom considered in a system context, i.e., leading research collaborations across European countries (Haegeman et al., 2013; Scarascia Mugnozza and Matteucci, 2012; Scarascia Mugnozza et al., 2012; Päivinen, 2011; von Teuffel, 2011). Consequently, measuring the forest research potential is a key-point to establishing a starting point to build up a common research framework in the Mediterranean forest sector but also a rewarding task for the management of an institution (MFRA, 2009). In this context, a better knowledge of forest research capacity is becoming a more and more important element for the improvement of efficiency of forest research institutions involved even if the scientific and technological cooperation with the developing world over the last forty years has gone through a number of overlapping phases and has reflected different approaches and concepts (CIFOR, 2004; Kowero and Spilsbury, 1997; Gaillard, 2001; von Teuffel, 2011; Päivinen, 2011).

According to MFRA (2009) and Houllier et al. (2005) forest research capacity refers to accomplish the following goals: (i) capacity to perform forest research according to EU policy, and (ii) capacity to produce and disseminate results and innovations among actors concerned with forest issues (i.e., stakeholders, scientific community and politicians), taking into consideration their wide diversity and thus orienting their activities according to their changing needs. The first goal is reached by capacity to perform forest research, i.e., attract research funds from forest projects via multidisciplinary skills held by personnel and consistency of budget allotted to cover all expenses for research. These abilities depend upon the research focus of the institutions and whether or not these are aligned with national and/or EU research priorities. The ability of an institution to win research funds will therefore depend somewhat upon its capacity to fit within these priorities. The second goal is reached by capacities to produce and consequently disseminate quality research results and innovations among concerned actors. We should note that these capacities could be inter-related because productivity and dissemination in research are affected by the extent to which the researcher has succeeded in gaining funds for research, and in as far as the allocation of funds is influenced by past productivity.

## 2. Materials and methods

### 2.1. Cluster analyses

For the forest research capacity indicators corresponding to the thirteen Mediterranean countries, we performed a cluster analysis to identify similarities and/or dissimilarities among them. Clustering is

loosely defined as "the process of collecting objects into groups whose members are similar in some way" (Kaufman and Rousseeuw, 2005). We considered it potentially useful to our aims due to its intrinsic capacity at grouping a set of unlabelled data. We used hierarchical clustering because it represents one of the popular supervised learning distances (Kaufman and Rousseeuw, 2005). One of the most important characteristics of hierarchical approach is the use of Euclidean distance, i.e., it measures the distance between two points as the hypotenuses of a triangle they form. Among the algorithms for hierarchical clustering, we selected weighted pair-group method with arithmetic averages (WPGMA) as single linkage rule. Single linkage algorithm is based on minimum distances, tending to form one large cluster with the other clusters containing only one or few objects each (Mooi and Sarstedt, 2011). We used this "chaining effect" to detect outliers among countries by plotting their distribution in two-dimensional spaces defined by relationships from each pair of indicators. This has allowed us to identify causal indicators that affected the clustering at country-scale. Due to the different scales of clustered indicators, we used the $z$ standardization to rescale each variable and to get the standard deviation of $\pm 1$. Data analyses were performed using Statistica6.0 software (StatSoft, Inc., Tulsa, OK, USA) and, when applicable, the statistical significance was set to $P < 0.05$.

### 2.2. How we collected information and extrapolated indicators

We used a simplified definition of "forest research institute" as follows: a forest research institute is a legal entity or a structural part of a legal entity in which research time of the personnel is entirely allocated to forest research. The inventory of forest research capacities was implemented by conducting a dedicated survey, which covered quantitative and qualitative information about the research capacities of forest research institutes and on institutions that have a funding role for forest research programs in thirteen countries affected by Mediterranean climate. These thirteen countries span from Northern Africa to Near East, Eastern Europe and to Southern Europe, including Algeria, Bulgaria, Croatia, France, Greece, Israel, Italy, Morocco, Portugal, Slovenia, Spain, Tunisia and Turkey (Fig. 1). We designed two questionnaires to obtain two types of information: (i) information about funds released from funding institutions for forest research programs. This questionnaire included information on funding released to forest research institutes by public bodies, funding agencies and private industries in order to quantify the budget allocated to forest research projects and the overall budget spent by Mediterranean forest research institutes (reported as average for years 2010 and 2011). The overall budget identifies the full budget dedicated to forest research, including contributions from government, funding agencies and private institutions as well as funds coming from competitive grants for research projects. These figures include salaries for permanent staff, functioning expenses and actual costs for research projects, considering also the salaries of non-permanent staff. We used common basic data like the Gross Domestic product (GDP) for overall budget comparisons to overcome difficulties in balancing out R&D expenses of countries with differences in price levels and over time (Frascati Manual, 2002). Regarding the budget of forest projects, we should note that the funded forest projects could have a different lifespan (i.e., different start and end dates); however, no historical track of previous funded forest projects was requested because we focused only on the "active" projects performed at the survey time. Hence, we expressed the budget allocated to forest projects as annual mean of an "active" project. (ii) Information about scientific research capacities and performances of the forest research



**Fig. 1.** Mediterranean countries involved in the survey.

institutes. This questionnaire included information about competencies, scientific products, staff and research lines from the scientific institutes involved in Mediterranean forest research. Regarding staff data, we should note that the definition of researcher varies across countries and across research institutes. In this study the research personnel was grouped into "total researchers" (i.e., permanent researchers and non-permanent researchers), whereas the permanent staff was characterized by permanent researchers, technical personnel and administrative personnel (i.e., everyone else who contributes to the research project in a technical and administrative aspect). Thus, in many research forest institutes the reported number of total researchers is less than the total number of employees.

Finally, the data gathered from questionnaires were used to assess the following indicators: (i) research lines performed in forest research; (ii) budget generated by forest projects; (iii) overall full budget spent for forest research; (iv) number of ongoing forest projects implemented; (v) total researchers, permanent staff and non-permanent staff deployed in forest research; and (vi) ISI papers published in forest subjects.

## 3. Results

### 3.1. Generating a Mediterranean forest research framework

Seventy-nine institutions (66 from forest research institutes and 13 from funding bodies) were surveyed over 13 countries (acronyms and full names are reported in Appendix A). There was a wide range of forest institutes dealing with forest related research issues in the Mediterranean area. Some 66 institutes were engaged in forest research and forest education as a main activity, including research institutes or Councils, and Universities with specific forest *curricula* and degrees. As shown in Fig. 2, 30 of these institutes were located in Southern Europe, 33 in Southeastern Europe and in the Near East, and 3 in Northern Africa. The research lines developed by these forest research institutes showed that the five forest topics of major concern were as follows: (i) ecological interactions, global and climate change, adaptation and genetic resources; (ii) forest inventory, planning, silviculture and sustainable management; (iii) forest health, pest control, effects of pollutants and BVOC; (iv) plant and animal biodiversity, protected area management; and (v) biomass production, bioenergy and agroforestry. On the contrary, the least addressed forest research lines were as follows: (i) assessment of ecological risks and natural hazards; (ii) botany and taxonomy, identification and classification of plant species; (iii) urban forestry, territorial planning and tree architecture and (iv) phytoremediation, phytodepuration and use of treated waste

water (Fig. 3). These results suggest a high geographic and thematic fragmentation, as many of the research institutes are dispersed within a country, and cover a wide range of forest research topics, leading to research teams below critical mass. This was probably due to two different reasons: either (i) to comply the national research priorities, or (ii) to be more involved in EU research frameworks.

### 3.2. Mediterranean forest research capacities inventory

The analysis of the indicators depicts very high differences across the thirteen Mediterranean countries (Table 1). The overall budget amounts to 259.5 M€ per year throughout the region. The highest overall budgets were spent by France (87.4 M€), Spain (54.1 M€) and Italy (50.8 M€), whereas the lowest overall budgets were spent by Morocco (0.60 M€), Tunisia (0.80 M€) and Bulgaria (1.8 M€). However, these differences are notably reduced by sharing the GDP for general research expenses. The budget allocated to forest projects and from competitive grants for Mediterranean forest research was 72.0 M€; whereas three countries, namely France, Spain and Italy, account alone for about 80% of the total budget of forest projects. The total number of forest projects per year was 565 (France not included), with Turkey showing the highest number of research projects (128). However, no clear relationship between the budget of forest projects and the total number of forest projects was found. This was because the mean financial size of forest research projects was quite variable from country to country. The mean budget per forest project was about 0.10 M€/project, where Portugal (0.2 M€/project) showed the highest budget followed by Italy (0.19 M€/project) and Spain (0.15 M€/project).

Forest research community consists of more than 3600 total researchers. Adding also staff deployed for technical and administrative activities, the result was a wide community of about 5600 people supporting forest research. The share of the four largest countries of the region, that is, France, Italy, Spain and Turkey, in this wide community of scientists and supporting staff, was again quite high, about 70% of total value, but less high than observed for budget (Fig. 4). It is also possible to balance out for the different costs of salaries among the different areas of the Mediterranean region. The ratio of non-permanent/permanent research staff was about 0.7 in the whole region, with large variations among countries: in Portugal, Slovenia and Greece this ratio was higher, varying between about 2.0 and 1.0 whereas for the other countries was much lower, below one. Moreover, the technicians and administrative staff to permanent staff ratio was slightly less than 0.5 throughout the region, with no large variations among countries.

ISI papers published in forest subjects were about 1250 per year, with five countries (France, Italy, Spain, Turkey and Greece) accounting
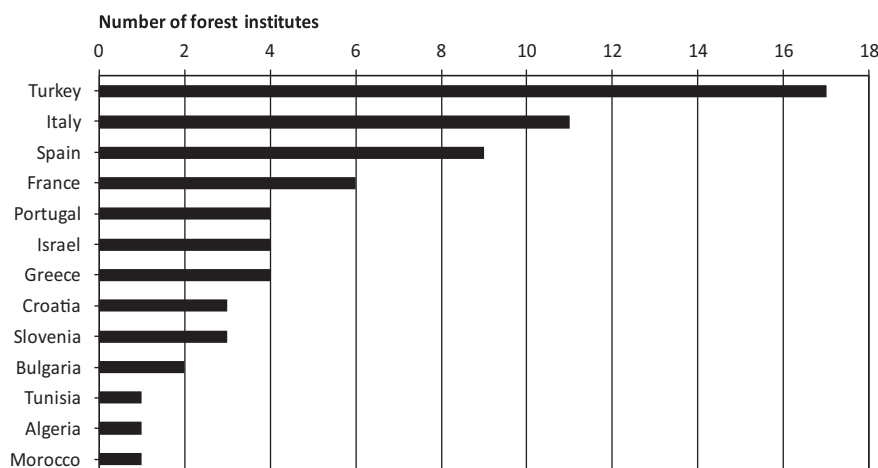


**Fig. 2.** Frequency of the number of forest research institutes involved in the survey.
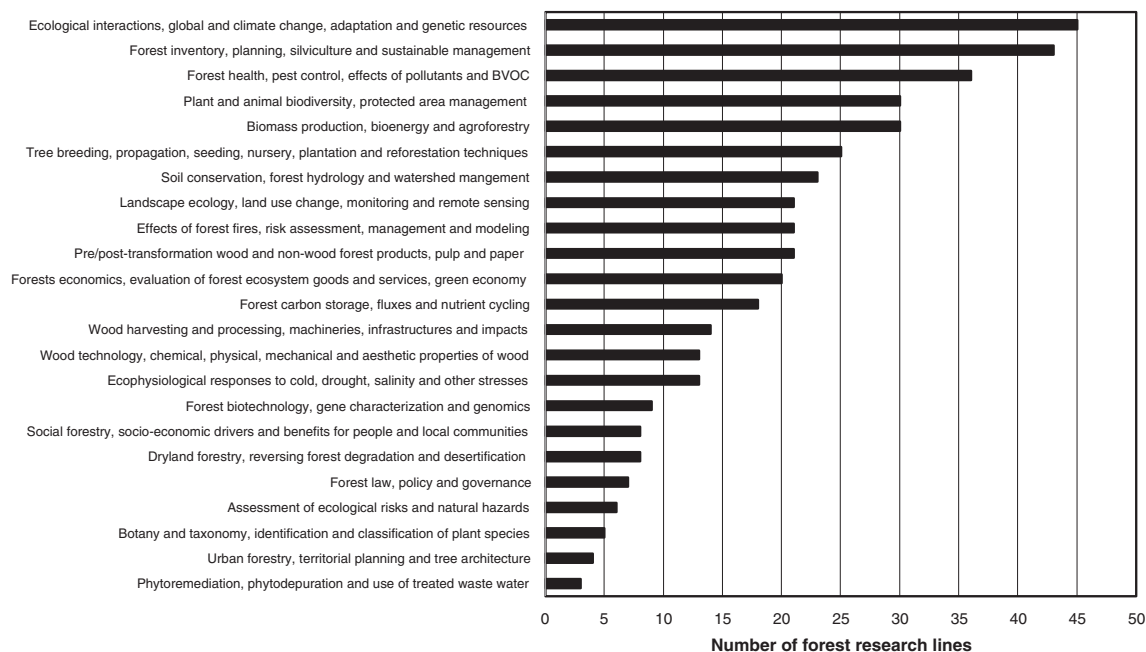
**Fig. 3.** Frequency of the most utilized forest research lines in Mediterranean forest research.

for about 80% of publication records. The international refereed journals mostly used to disseminate results and innovations of forest research as scientific papers were about 60, with variable impact factors (IF at 2011) (data not shown). However, the seven most utilized journals were as follows: Forest Ecology & Management (IF: 2.74), European Journal of Forest Research (IF: 1.98), International Journal of Wildland Fire (IF: 2.23), New Phytologist (IF: 6.64), Tree Physiology (IF: 2.88), Annals of Forest Science (IF: 1.78) and Canadian Journal of Forest Research (IF: 1.69) (Fig. 5). The nine most prestigious journals, with the highest IF, utilized for publishing on forest science issues were as follows: Nature (IF: 36.28), Science (IF: 31.2), Ecology Letters (IF: 17.55), Trends in Ecology & Evolution (IF: 15.74), Trends in Plant Science (IF: 11.04), The Plant Cell (IF: 10.22), PNAS (IF: 9.68), Trends in Biotechnology (IF: 9.48) and Frontiers in Ecology & Environment (IF: 9.11) (Fig. 6). However, these results should be interpreted carefully and consistently with the background of the single countries and the overall claim that research can inform policy-making. In some countries, an English-language publication is probably useless for forest practitioners or political actors who are much more familiar with their native language. Additionally, the scientific requirements of peer-reviewed publications are often in contrast with the practice-oriented needs of practitioners (McKinley et al., 2012).

## 4. Discussions

### 4.1. Clustering Mediterranean forest research

The existence of similarities and/or dissimilarities in forest research capacities across the thirteen Mediterranean countries was broadly supported by the cluster analysis dendrogram, which grouped those countries with similar capacities in forest research (Fig. 7). The cluster analysis dendrogram revealed two groups: the first one includes Turkey, Italy, Spain and France with 28% of similarity (Italy, Spain and France showed 46% of similarity); the second includes eight countries

**Table 1**
Budget, number of ongoing forest projects, ISI papers and personnel in Mediterranean countries leading forest research.

| | Budgets | | RDE[a] | Projects | Papers | Staff | | |
|---|---|---|---|---|---|---|---|---|
| | Overall | Forest projects | (% of GDP) | Forest | ISI | Permanent | Non-permanent | Total researchers |
| | M€ yr$^{-1}$ | | | Nr yr$^{-1}$ | Nr yr$^{-1}$ | Nr | | |
| France | 87.4 | 21.2 | 2.25 | na | 261 | 878 | 356 | 777 |
| Spain | 54.1 | 17.0 | 1.38 | 111 | 221 | 481 | 335 | 566 |
| Italy | 50.8 | 16.4 | 1.26 | 87 | 226 | 551 | 322 | 652 |
| Turkey | 27.7 | 5.1 | 0.85 | 128 | 151 | 858 | 104 | 548 |
| Croatia | 10.1 | 3.0 | 0.76 | 73 | 24 | 286 | 38 | 192 |
| Portugal | 8.0 | 2.2 | 1.56 | 11 | 108 | 114 | 166 | 217 |
| Greece | 6.7 | 2.1 | 0.68 | 46 | 135 | 143 | 154 | 204 |
| Slovenia | 6.6 | 3.3 | 2.29 | 35 | 38 | 64 | 66 | 100 |
| Bulgaria | 1.8 | 0.7 | 0.59 | 34 | 21 | 245 | 17 | 145 |
| Algeria | 5.0 | 0.6 | na | 24 | 9 | 196 | 0 | 135 |
| Tunisia | 0.8 | 0.2 | 1.10 | 5 | 29 | 70 | 12 | 42 |
| Morocco | 0.6 | 0.2 | 0.73 | 11 | 10 | 77 | 10 | 49 |
| Israel | na | na | na | na | 16 | 36 | 15 | 51 |
| Sum | 259.5 | 72.0 | | 565 | 1249 | 3999 | 1595 | 3678 |

[a]  RDE indicates the share of Gross Domestic Product (GDP) for General Research Development Expenditures (RDE) (average for years 2010 and 2011). Source: The World Bank Group: http://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS/countries/IT?display=default.
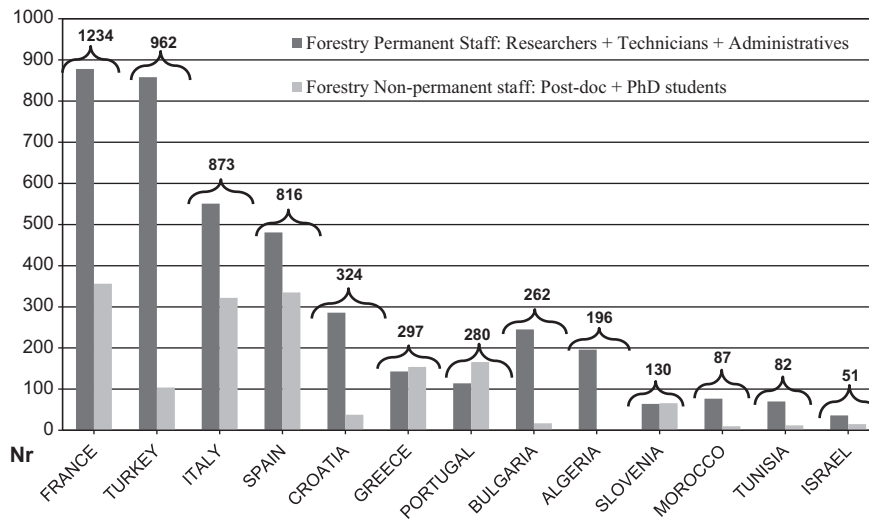
**Fig. 4.** Total staff deployed in Mediterranean forest research.

(Morocco, Tunisia, Algeria, Bulgaria, Croatia, Slovenia, Greece and Portugal) with about 40% of similarity (69% of similarity excluding Croatia). This grouping is consistent with the different investments spent by each country for Mediterranean forest research as reported by number of studies dealing with the general trends of forest research funding in Europe, and with the impact of private sector funding in forest research capacities in Europe (Bystriakova and Schuck, 1999; FAO, 1995; Hellström, 1995; Hellström et al., 1998; Houllier et al., 2005). We should note, however, the large investments of Slovenia and Portugal in general R&D, as they spent 2.29 and 1.56% of GDP respectively. According to data provided by Western European countries, the major economies France and Germany, followed by Sweden and Finland, have the largest research personnel in forest research. The abovementioned studies also showed that in Europe 40% of forest research was conducted by universities, 49% by public research organizations and 9% by private research organizations.

Even if the overall budget significantly differs among countries, the share of GDP for general research expenses showed that half of countries invested more than 1% of GDP, with France and Slovenia reaching more than 2%. However, we should note that France, as one of the most important economies in Europe, may be much more influenced by the EU research framework than by its characteristics as a Mediterranean country. This could also be the case of Spain and Italy, whereas other countries could be much more interested in investing in regional and local research issues. We should note that the high forest research expenses of these countries were covered by institutions committed to broad agricultural research, as is the case of INRA (France), INIA (Spain) and CRA (Italy). For instance, the very high overall budget observed for France was mainly due to the large contribution made by INRA, with its main forest departments (i.e., INRA-EFPA, INRA-EA and INRA-UEFM) where most of the forest research is carried out; however, other two research institutes were also considered, that is, FCBA and IRSTEA and an academic institution as AgroParisTech. We should note that only a minor part of the research activities and research staff in France are devoted to the Mediterranean forest research, while a large part of them are linked to continental and oceanic forest environments. The overall budget raised by Spain to finance forest research regards mainly four scientific institutions: INIA, CREAF, CTFC and UCLM University. The overall budget for Italy pertains mainly to CRA, a scientific organization where agricultural sector prevails and which its forest department represents a *quota* of 16% of the overall budget. Other relevant forest research institutes are CNR, with two departments partly dedicated to forest and environment research, the Edmund Mach Foundation, a regional research institute, and several universities all over
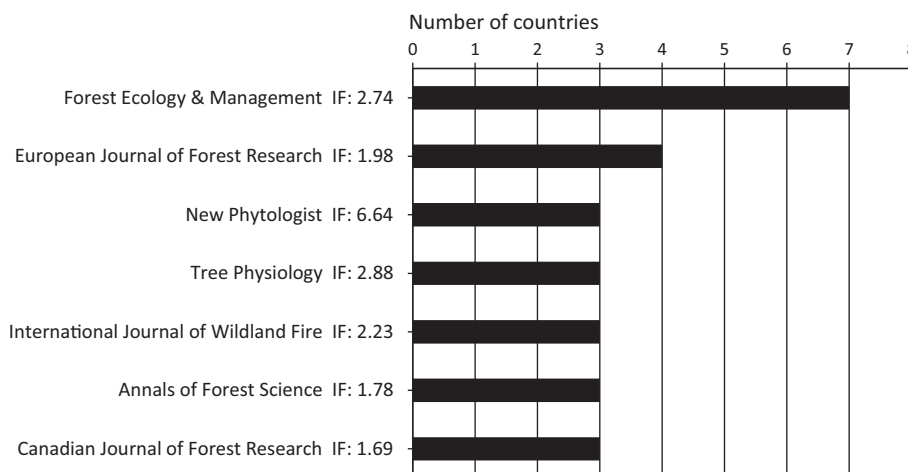


**Fig. 5.** Frequency of seven most popular ISI journals utilized in Mediterranean forest research.
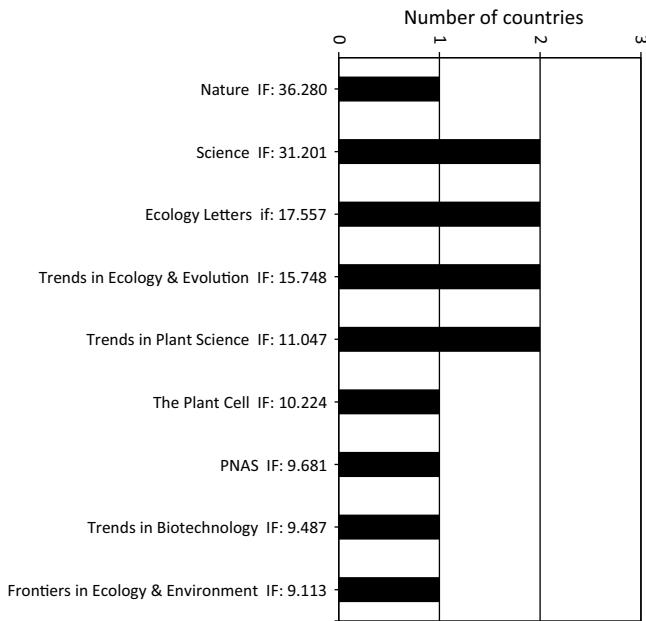
**Fig. 6.** Frequency of nine most prestigious IF journals (with the highest IF) utilized in Mediterranean forest research.

Italy. A different situation is found in Turkey, where the largest share of the overall and forest project budgets is managed by universities (mainly the Forestry Faculties of Istanbul, Karadeniz, Bartin and Suleyman Demirel universities). However, it should be highlighted that the investments on forest research in the different Mediterranean countries, as reported in this study, refer to the actual overall costs of research activities calculated with official exchange rates of different currencies used in non-EU countries to Euro, without adjusting the budget figures to reflect different costs of living. This obviously implies that the role of forest research in many non-EU countries is underestimated.

### 4.2. Relationships among indicators

Taking into consideration all possible relationships among the main forest research capacity indicators, we observed overall positive

relationships with regression coefficients usually greater than 0.5 (apart those between number of forest project/non-permanent staff and permanent staff/non-permanent staff). Hence, in Fig. 8 the blue, green and gray areas identify the clustered country groups, while countries highlighted by red circle indicate outliers in the relationships. Plotting the relationship lines across the clustered country groups, we obtained simple linear regressions between the pair of indicators analyzed. The overall picture emerging from this analysis showed that each indicator can order two clustered groups quite uniformly, that is, each country of group A has lower values than each country of group B in quite all cases. This implies that a linear positive relationship between each pair of indicators seems to emerge. However, once we analyzed the distribution of the pair of indicators within each country group, a different picture emerged, especially when one of the pair of indicators is number of forest projects. This means that the positive linkage with other indicators was less significant in group A and is eventually reverted within group B. As a result, the number of forest projects was higher for countries of group B compared to the other ones, but they were not positively related with other indicators and, as far as group B is concerned, the relationships seem to be reverted. A weakening of the increasing relationships in the number of non-permanent staff when moving from the overall picture to the group analysis occurred, especially when they were analyzed by relationships including other indicators of human capital (i.e., permanent staff and total researchers). Besides, for group A the "ISI papers" indicator was more related to non-permanent staff than permanent staff.

The unrelated nature of number of forest projects justifies the apparent outlier behavior of Croatia and Portugal. Besides, the analysis of outliers explains the weak linkage between Turkey and its group. The main difference between Turkey and the group of Western Mediterranean countries lies on the relatively low level of non-permanent staff. This difference can be partly imputed to the specific labor market legislation (and partially to the statistical definition of non-permanent) of this non-EU country with respect to other countries of group B. Yet, we observed different correlations among the staff relationships. This was because staff capacities depict a rather large research community with a substantial amount of resources in terms of both personnel (3700 researchers and 5600 total staff) and investments (260 M€ per year). Compared to this study, a lower number of total researchers deployed in forest research (i.e., 3000) was noticed by Houllier et al. (2005) for the whole of Europe, though they surveyed many less forest institutions (34) than this study did (79). The ISI paper relationships showed good
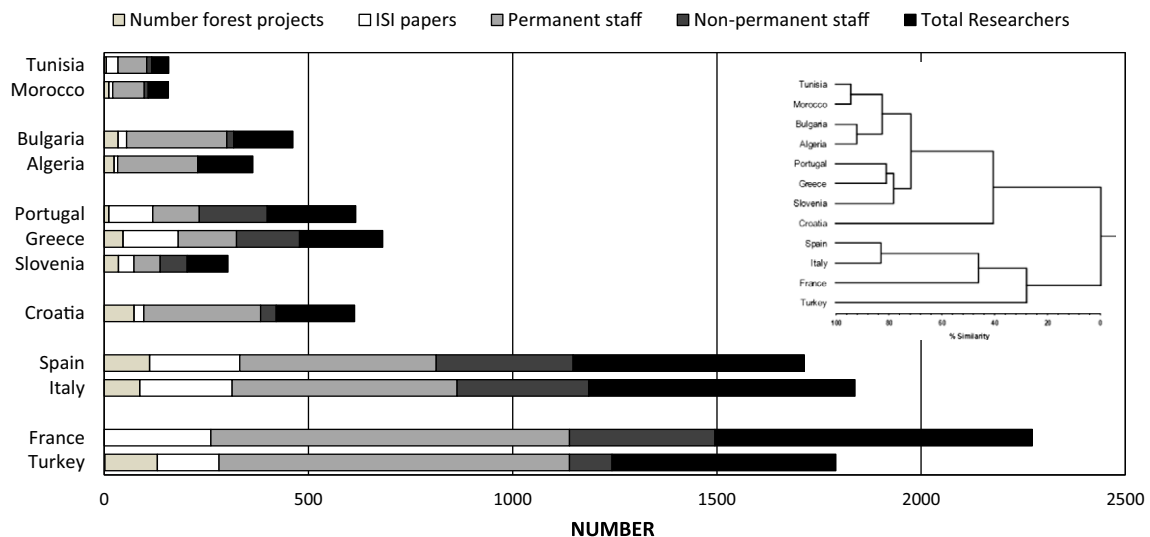


**Fig. 7.** Number of ongoing forest projects, number of yearly ISI papers published in forest subjects and number of total staff deployed in forest research, together with the cluster analysis dendrogram grouping the Mediterranean countries with similar performances in forest research capacity. Note that the number of ongoing forest projects for France is lacking.
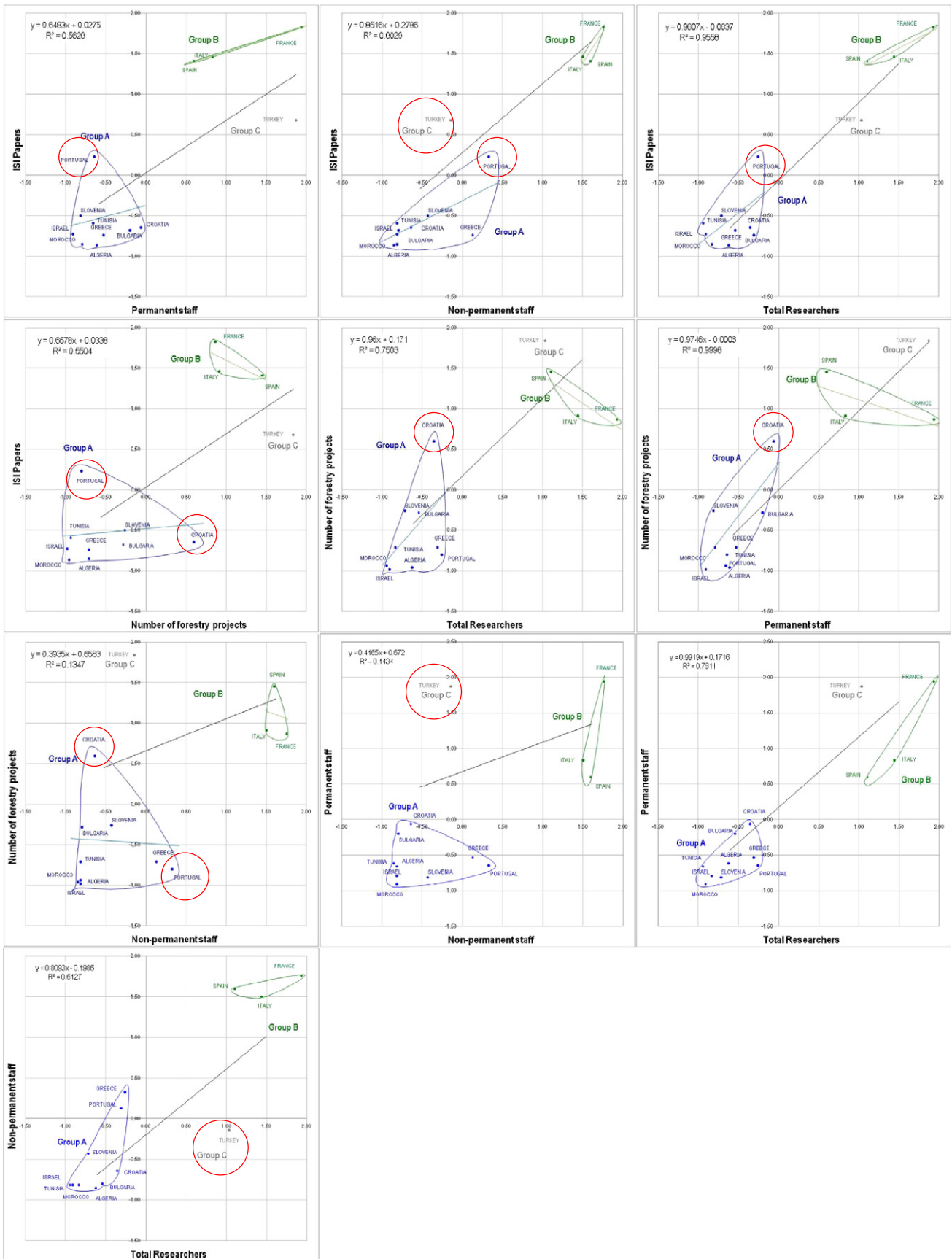
Fig. 8. Location and relationships of countries in the two-dimensional spaces defined by each pair of indicators.

correlations with staff indicators, especially with total researchers ($R^2 = 0.95$). This is why if we compare the number of publications issued per year to the number of researchers across countries, both permanent or in total (permanent and non-permanent) the overall ratio is quite stable: about 0.6 paper/researcher in the former case and 0.3 in the latter. Obviously, there were also large differences from country to country.

On the other hand, it is clear that the almost 66 forest research institutes, including higher education institutions dealing with forest related research, depict a situation of high geographic and thematic fragmentation, as many of the research institutes are dispersed within a country, and cover a wide range of research topics. Moreover, they are unevenly distributed in terms of size, budget and capacity throughout the countries of the Mediterranean region.

## 5. Conclusions

This study has provided further scientific evidence to enrich existing literature on knowledge mobilization, innovation systems and research cooperation in the forest sector. Results and innovations produced by Mediterranean forest research have been quantified and publication trends have been described. We also showed the level of expenses which are needed to support these research systems. By cluster analyses, we were able to show the share of similarities and dissimilarities of forest research capacities in the Mediterranean area and we identified the main causal indicators that affected the clustering. The clustering indicated several research dissimilarities due to unequal distribution in terms of size, budget, knowledge mobilization, innovation systems and some specific factors such as local labor market legislations, level of involvement in EU research frameworks, extent of adherence to national research priorities and whether or not these are aligned with EU research priorities. All this implies that to address the challenges in a changing word, the forest research sector should regularly reconsider its strategies and actions, including the institutional design to get the necessary critical mass through mechanisms of alignment of programs and through renewed cooperation. New ways to overcome the current situation should be pursued through ambitious long-term research partnerships and networking involving the use of participatory research, research capacity building, knowledge mobilization and innovation systems.

## Acknowledgments

## Appendix A. Forest research institutes and funding bodies (in bold) involved in the survey

| Forest institutes and funding bodies | Country |
|---|---|
| NIFR, National Institute of Forestry Research | Algeria |
| EFA, Executive Forestry Agency | Bulgaria |
| FRI-BAS, Forest Research Institute, Bulgarian Academy of Sciences | Bulgaria |
| **EFA, Executive Forestry Agency (Funding Body)** | Bulgaria |
| IAC, Institute for Adriatic Crops and Karst Reclamation, Department of Forestry | Croatia |
| University of Zagreb, Faculty of Forestry | Croatia |
| HSI, Croatian Forest Research Institute | Croatia |
| INRA-EFPA, National Institute Agricultural Research, Department Forest, Grassland and Freshwater Ecology | France |
| INRA-EA, National Institute Agricultural Research, Department Environment and Agronomy | France |
| INRA-UEFM, National Institute Agricultural Research, Grassland, Freshwater Ecology and Mediterranean Forest Experimental Unit | France |
| IRSTEA-EMAX, Research Institute Forest Science and Tech. on Environment and Agriculture Mediterranean Ecosystems and Risks | France |
| FCBA, Forêt Cellulose Bois-Construction Ameublement | France |
| AGROPARISTECH, Institute of Technology for Life, Food and Env. Sciences, Dep. Agronomy, Forestry, Water and Environ. Sci and Tech. | France |
| **MAAF, French Ministry of Agriculture, Food and Forest, (Funding Body)** | France |
| **FRB, Foundation for Research on Biodiversity, (Funding Body)** | France |
| NAGREF-FRI: National Agricultural Research Foundation, Forest Research Institute, THESSALONIKI | Greece |
| NAGREF-FRIA, National Agricultural Research Foundation, Forest Research Institute, ATHENS | Greece |
| FFNE, University of Thessaloniki, Faculty of Forestry and Natural Environments | Greece |
| DFNEM, Kavala Institute of Technology, Department of Forestry and Natural Environment Management | Greece |
| WIS, Weizmann Institute of Science, Faculty of Chemistry, Dep. of Environmental Sciences and Energy Research | Israel |
| ARO, Agricultural Research Organization, Agronomy and Natural Resources | Israel |
| BIDR: University of the Negev, Jacob Blaustein Institute for Desert Research | Israel |
| HUJ, Hebrew University of Jerusalem | Israel |
| CRA-DAF, Agricultural Research Council, Department of Agronomy, Forestry and Land Use | Italy |
| UNIMOL-DiBT, University of Molise, Department of Biosciences and Territory | Italy |
| UNITUS-DIBAF, University of Tuscia, Department for Innovation in Biological, Agro-food and Forest systems | Italy |
| UNIFI-DEISTAF, University of Florence, Department of Agricultural and Forest Economics, Engineering, Sciences and Technologies | Italy |
| CNR-IBAF: National Research Council of Italy, Institute of agro-environmental and forest biology | Italy |
| CNR-ISAFOM, National Research Council of Italy, Institute for Agricultural and Forestry Systems in the Mediterranean | Italy |
| CNR-IPP, National Research Council of Italy, Institute for Plant Protection | Italy |
| UNIPD-TESAF, University of Padova, Department of Land, Environment, Agriculture and Forestry | Italy |
| UNITO-AGROSELVITER, University of Turin, Department of Agronomy, Forest and Land Management | Italy |
| EDMUND MACH, Edmund Mach Foundation | Italy |
| CNR-IVALSA, National Research Council of Italy, Trees and Timber Institute | Italy |
| **MIPAAF, Ministry of Agriculture Food and Forest Politics (Funding Body)** | Italy |
| **REG, Inter-regional network for Forestry researches (Funding Body)** | Italy |
| CRF, Forestry Research Center | Morocco |
| CBQF, Centre for Biotechnology and Fine Chemistry | Portugal |
| CEABN, Technical University of Lisbon, Centre for Applied Ecology, School of Agriculture | Portugal |
| CERNAS, Research Centre on Natural Resources, Environment and Society | Portugal |
| CFE UC, University of Coimbra, Centre for Functional Ecology | Portugal |
| **FCT: Foundation for Science and Technology (Funding Body)** | Portugal |
| UL, University of Ljubljana, Biotechnical Faculty, Department of Forestry and Renewable Natural Resources | Slovenia |
| ERICO, Ecological Research and Industrial Cooperation | Slovenia |
| SFI, Slovenian Forestry Institute | Slovenia |

**Appendix A** *(continued)*

| Forest institutes and funding bodies | Country |
|---|---|
| **MAE, Ministry of Agriculture and Environment (Funding Body)** | Slovenia |
| CEIA3, Agrifood Campus of International Excellence | Spain |
| IUGFS, University of Valladolid, Sustainable Forest Management Research Institute | Spain |
| CREAF, Centre for Ecological Research and Forestry Applications | Spain |
| CTFC, Forest Sciences Center of Catalonia | Spain |
| UAH, University of Alcala | Spain |
| UCLM, University of Castilla La Mancha | Spain |
| CETEMAS, Forest and Wood Technological Center | Spain |
| UDL, University of Lleida | Spain |
| INIA, National Institute for Agricultural and Food Research Technology | Spain |
| **MINECO, Ministry for Economy and the Environment (Funding Body)** | Spain |
| INRGREF, National Institute for Rural Engineering, Water and Forests | Tunisia |
| EBSFRI, Eastern Black Sea Region Forestry Research Institute | Turkey |
| WEBFRI, The Western Blacksea Forestry Research Institute | Turkey |
| SDU, Suleyman Demirel University | Turkey |
| KAE, Poplar and Fast Growing forest Trees Research Institute | Turkey |
| OATIAM, Forest Tree Seeds and Tree Breeding Research Directorate | Turkey |
| OTEAE, Forest Research Institute for Soil and Ecology | Turkey |
| IU OF, Istanbul University, Faculty of Forestry | Turkey |
| ACUOF, Artvin Coruh University, Faculty of Forestry | Turkey |
| CNUOF, Cankiri Karatekin University, Faculty of Forestry | Turkey |
| CAFRI, Central Anatolian Forestry Research Institute | Turkey |
| EFRI, Ege Forestry Research Institute | Turkey |
| DOA, Eastern Mediterranean Forestry Research Institute | Turkey |
| EAFRI, Eastern Anatolian Forestry Research Institute | Turkey |
| SEAFRI, Southeastern Anatolian Forestry Research Institute | Turkey |
| KTU, Karadeniz Technical University | Turkey |
| BOF, Bartin University, Forestry Faculty | Turkey |
| SAFRI, Southwest Anatolian Forestry Research Institute | Turkey |
| **OGM, General Directorate of Forest (Funding Body)** | Turkey |
| **SDU, Suleyman Demirel University (Funding Body)** | Turkey |
| **IU, Istanbul University (Funding Body)** | Turkey |
| **CNUOF, Cankiri Karatekin University, Faculty of Forestry (Funding Body)** | Turkey |
| **TUBITAK, The Scientific and Technological Research Council of Turkey (Funding Body)** | Turkey |

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