Mediterranean Forest Research Agenda (MFRA)
Scientific advancements from 2010-2020 & Looking ahead to 2030: Survey synthesis

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Introduction/Survey approach

The first Mediterranean Forest Research Agenda (MFRA), launched in 2010, and was prospective for the period from 2011 to 2020. The research topics highlighted by the Agenda's four thematic areas were co-developed through a participatory process involving leading researchers, stakeholders, and other experts from across the EFIMED network, and the Mediterranean forest policy and management community. As we close the chapter on the MFRA 2010-2020, and look forward to a new MFRA 2021-2030, we sought to identify the most important research, significant breakthroughs and innovations that were completed within each thematic area over the past decade. We engaged the same EFIMED network and the broader Mediterranean community to reflect on how far the objectives of MFRA 2010-2020 have been met.

We also sought to find out what work remains to be done: we asked these same experts to help us identify the key research challenges for the next decade, to be placed in the spotlight by MFRA 2021-2030. The contributions of research leaders in Mediterranean forest studies from Europe, Middle-East, North Africa and around the globe will play a role in shaping the future of the Mediterranean Forest Research Agenda.

Due to the difficulties posed by the global COVID-19 crisis, this survey of Mediterranean experts was carried out online, which presented limitations, but also facilitated access in a way that would not have been possible if networking were carried out through in-person events. The results thus constitute inputs from key informants, rather than a comprehensive report of views across the field.

Therefore, the responses analyzed in this document may present somewhat more selected views of Mediterranean forest research over the past decade, as of the perceived research priorities across the Mediterranean community for the next ten years. Naturally, the respondents who gave the most in-depth answers provided the most material to be interpreted here. However, we feel that it is a firm foundation to assess the successes and limitations of MFRA 2011-2020, and to build a dialogue on the priorities of the new MFRA 2021-2030, including through additional contributions we hope to gather through online or hybrid seminars with Mediterranean experts in 2021.

Evaluating MFRA 2011-2020

The Mediterranean Forest Research Agenda presented a common vision of the challenges of Mediterranean forest, and described the main research priorities for forestry in the region during 2011-2020. The MFRA 2011-2020 was structured around four strategic research priorities to provide a scientific framework with which to meet the important challenges ahead (see below). Survey respondents reflected on how the MFRA has been implemented over the past ten years, supporting the creation of a Mediterranean forestry knowledge triangle of research, education and innovation as well as a geographic triangle with its vertices in Mediterranean Europe, North Africa and the Middle East. The reflections of the experts who participated in the survey have been organized below by the thematic areas highlighted by MFRA 2011-2020, and answers have been synthesized to give an overview of the key scientific impacts and innovations that have been achieved – as well as the work that still needs to be done on the objectives of the MFRA.

Respondents also highlighted important projects and publications carried out within each of these thematic areas over the past ten years: these can be seen here. While these lists are not comprehensive, they demonstrate the incredible reach of the MFRA's impact on Mediterranean forest research and action.

Thematic Area 1: The impact of climate and land-use change on Mediterranean forest ecosystems

Survey respondents enthusiastically identified breakthroughs in the field of climate and land-use change on Mediterranean forest ecosystems that were realised by the scientific community during the period 2011-2020. These scientific advances testify to a broad academic focus over the past decade, with research responding to the urgent threat faced by climate change, new technological advancements to enhance data availability, and novel approaches to science-based forest management that have served to bridge the gap between science and practice.

Climate change

Political consensus and enhanced scientific certainties on climate change and climate-related disturbances like drought, fire risk, and other environmental challenges were cited as a major scientific achievement both in the Mediterranean and worldwide by several survey participants. Similarly, better knowledge of climate-ecosystem interaction, especially the impacts of climate on forest structure and tree growth on multiple scales has provided a firm foundation for science-based forest management and policy, as well as future research. More targeted research efforts were also noted, such as the study of the molecular basis of plastic responses of forest tree species to environmental challenges, attempts to disentangle the effect of individual stressors of climate change and the effect of other abiotic stress such as atmospheric pollution, and the potential of management choices to impact climate adaptation and resilience, with a particular mention of urban forestry as an area for fruitful future study. Survey respondents noted that these scientific breakthroughs helped to fuel advancements in climate-based models for species distribution, forest growth and genetic structure of populations.

New technologies

Enhanced technological approaches were cited by survey respondents as resulting from, and fostering scientific advancement on climate and land-use change in the Mediterranean. The refinement of climate

models and the possibility of defining more accurate scenarios, including through the development of GIS-based databases of genetic resources to underlie research strategies, has greatly influenced the scope of research in this field. Similarly, one respondent highlights, the "availability of large datasets of species' functional traits and relevant research on how metrics based on functional traits are correlated with ecosystem functions and services is greatly increasing our ability to predict the effects of forest management, land use change and climate change on ecosystem services and functions at different scales." These improved databases provide a strong, science-based platform for adaptation and mitigation strategies, including supporting green infrastructure. Finally, technological advancements in producing high-quality, high-resolution datasets using remote sensing and machine learning have resulted in unprecedented, homogenous, and accessible data for land-use change research. In particular, respondents pointed to the Copernicus Open Access Hub (including Sentinel data products), UAV-based remote sensing data, ground-based and aerial LIDAR, and machine learning algorithms as key resources that have emerged over the past ten years. Finally, some survey participants referenced advances in forest genetic research as key for climate change and land-use science: in particular, the availability of new genetic material (e.g. Eucalyptus hybrids) and the development of structural and functional genomics for trees have improved knowledge about their adaptive responses.

Forest management

Beyond these advances in climate change research and new data and technologies, survey respondents highlighted how this novel scientific information has been translated into real-world practice. These responses underline the importance of connecting research breakthroughs to on-the-ground solutions, and imply that effective implementation is, on its own, a significant scientific achievement. One example of this connection, given by a respondent, is the increased attention on the functions and services offered by Mediterranean forests, and attempts to identify tradeoffs and thereby optimize a desired set of services at the landscape level. Another respondent similarly highlighted a growing focus over the past decade of ecosystem mosaics, multi-functional ecosystems, and mixed forests as a key approach to improving landscape resilience in the face of climate change. Improved monitoring was also mentioned in the context of emerging pests and diseases, and a general increase in awareness for ecosystem changes exacerbated by climate change. Furthermore, a wide range of decision support systems (DSS) have been developed and used for effective decision-making processes. DSS can also contribute to knowledge bases that improve our understanding of forest dynamics under a mix of management strategies, focusing on the integrated use of various ecosystem services within the multipurpose forest management planning framework.

Thematic Area 2: Integration of the risk of forest fires in land-use and landscape planning and management

The risk of forest fires in Mediterranean areas has perhaps been an even more urgent topic from 2011-2020 than expected when the first MFRA was instated. This is surely evidenced by the continued focus on climate change impacts and forest disturbances in the proposed topics for the MFRA 2021-2030, as well as the suggestions from survey respondents to more explicitly include the study, prevention and management of megafires in the forthcoming agenda. In spite of the significant research and actions that must still be taken to face this growing threat, participants identified several key scientific contributions over the past ten years, in particular in enhanced understanding and modelling of fire regimes, fuel types and improved theories and approaches for fire management.

Fire regimes

At a basic level, respondents felt that increased certainty and consensus on the impact of climate change on fire regimes, as well as generalized assessment of fire regime changes, drivers, and emerging extreme wildfire events, represent a major area of new knowledge gained during the last decade. Similarly, more nuanced knowledge on fire ecology, including a better understanding of natural versus human-related impacts on the fire regime, and community/landscape-level resilience have put researchers and practitioners in a better position to predict and mitigate extreme fire events. Respondents pointed to innovative approaches to wildfire monitoring and modeling of fire risk, fire behavior, and burned area developed since 2010 as key factors in improving the prediction and response to fire and extreme events.

Fire management

Building on this improved understanding of fire regimes, survey participants highlighted the improvements in scientific research on fire management. To this point, they cited better knowledge of the effectiveness of fuel management treatments, with several respondents pointing out the importance of developments in prescribed burning approaches. Within the broader category of fire management, respondents noted important breakthroughs on risk assessment and awareness surrounding the crucial area of the wildland-urban interface, pointing out novel approaches in fire safety educational campaigns, trainings and the significant achievements of social participation in research. In a similar vein, the development of decision support models in combination with advanced management planning methods have broken ground in helping policymakers and communities design more resilient landscapes. This support, according to those surveyed, extends to better knowledge of the effectiveness of post-fire restoration and rehabilitation: a particularly relevant field of study following the devastating fires of 2017 across the Mediterranean. Several respondents felt that economic valuation of forest fire prevention and suppression activities, as well as cost-effective resilience approaches, were both areas of important achievements over the past ten years, and also a topic in urgent need of future research.

This sense of still urgent research and action led respondents to note that, despite the significant academic and scientific advances to-date, there remains a gap between these studies and their local applicability, including a need for better connections between scientists and politicians, improved transfer of knowledge to operational fields, and improved technical references and financial solutions for implementation.

Thematic Area 3: Policy, economic and institutional aspects for sustainable provision of forest goods and services

Although fewer respondents reflected on this thematic area, those who did highlighted key advancements on the sustainable provision of goods and services in academia since 2010. Considering that these topics were relatively novel concepts during the drafting of the first MFRA, the impact of ten years of research is clear in the popularity and ubiquity of forest ecosystem services as a consideration for forest policy at various scales, as an accepted and widely used conservation tool, and as an area of continued interest and innovation. Respondents recalled foundational breakthroughs on valuation and strengthening institutional and civil structures that have helped propel this topic academically and practically. Detailed spatial data and overlay of maps about the different type of environmental services

provided have allowed for new dimensions in the analysis of tradeoffs and synergies in the management of forests.

Valuation and traceability

Pointing especially to the economic aspects of sustainable provision, those who participated in the survey highlighted the importance of breakthroughs in valuing forest goods and services. In particular, the valuation of forest biomass as a source of energy, and of the cultural-spiritual forest ecosystem services made progress. These latter, including cultural heritage, health and wellness, and recreation, are growing areas of research focus that have emerged from the work of the last ten years. Additionally, the development and implementation of methodologies for tracing wood supply chains was noted as being especially important for value chain analysis.

Institutional and civil structures

Also related to the governance side of sustainable forest provision, survey respondents listed several national- and local-scale advancements – both academic and practical – to provide an institutional foundation for goods and services provision. At the national level, harmonization of forest inventories, transnational experimental networks, and the creation of a forest low-carbon label have been important developments. One respondent indicated that the integration of forest models and management objectives into broader frameworks, such as ecosystem services or the SDG, has been an important structural support for research and practical implementation over the past decade. Finally, respondents pointed to local civil structures, such a social participation, conservation schemes, and work with private forest owners to understand local forest interests have been important areas of research focus. That said, one respondent highlighted the "difficulty of getting the attention of public authorities on forest values other than basic wood products and wood energy," suggesting that, while research on ecosystem services valuation has developed well over the past decade, more and different work may be needed in the next ten years to promote public and political interest in forest ecosystem services.

Thematic Area 4: Forest and woodlands in the context of integrated management of land resources: models and decision systems for optimising multi-objective and multi-actor problems

Regarding research innovations in the area of integrated forest management, respondents were eager to share both successful examples of major projects launched between 2010 and 2020 (such as StarTree and NOBEL, among many others), and to air their sense of urgency that this area of research remains a key gap for Mediterranean forests. One respondent remarked that it is "crucial to be included in the new research agenda". Among those efforts that were lauded by respondents for their contributions were the H2020 project INCREDIBLE, which focuses on non-wood forest products, and novel academic research on green chemistry. Beyond these projects, respondents highlighted advancements in technology, as well as a greater focus on multifunctional management and stakeholder engagement that have emerged to support integrated natural resource management in the Mediterranean.

New technology and data

Similar to the advancements cited in Thematic Area 2, relating to forest fires, broader developments in easily accessible high-resolution, high-quality imagery have jump-started research in many forest-related fields. Remote sensing and airborne data, such as from LIDAR and UAVs, are particularly well-suited to forest management, as they present an excellent way of monitoring land-use change and forest cover, and provide a seemingly endless source of historical and near-real time homogenous data.

This is especially true when combined with emerging machine learning algorithms, which make processing large amounts of data much quicker and easier. Respondents also mentioned the more generalized use of models and decision-support systems, as they have had a significant impact as tools for forest management and policy design at various scales.

Multifunctional management

New technologies have over the last decade increasingly supported breakthroughs in multifunctional management. One respondent said these breakthroughs included "the development of process-based models to simulate growth under climate change, of advanced multiple criteria spatial optimization management planning methods and of computer based tools that combine the functionalities of knowledge based systems and decision support systems." Spatial optimization, beyond just timber, was also mentioned as a key support of the ecosystem services approach by another respondent (see also above).

Stakeholder engagement

Management with multiple criteria in mind is not limited to simply biophysical applications: respondents noted the significance of an increase in focus over the last ten years on stakeholder involvement in management planning and decision-making. They cited progress in both horizontal and vertical stakeholder integration. One respondent lauded this progress, positing that "these breakthroughs contributed to a better representation of forest ecosystem management planning problems, to facilitate the engagement of decision makers and stakeholders and to enhance planning processes and management plans".

Looking Forward to MFRA 2021-2030

Proposed research themes

The research themes proposed to the survey participants were the result of an internal deliberation process with external inputs to identify some of the most salient areas for future Mediterranean forest research. The process of identifying these proposed themes began in July 2019, aiming to build on the efforts achieved during the first MFRA 2011-2020 and with guidance from EFIMED's world-class research and networks as to the most pressing issues facing Mediterranean forestry now and in the future.

These proposed themes are:

- **Theme A**: Conservation and management of biodiversity and forest genetic resources
- **Theme B**: Forest resilience in a context of global change related forest disturbances
- **Theme C:** Forest management addressing trade-offs and synergies between multiple ecosystem services
- **Theme D**: Social and business innovations and policy instruments to implement the Mediterranean forest-based bio-economy

In particular, Theme A on biodiversity was not highlighted in the previous MFRA, and is a very important topic especially for the Mediterranean as a biodiversity hotspot that is also suffering from huge loss in biodiversity. Theme B, covering the perennially important themes of climate change and fire that were also tackled in the first MFRA, now focuses on taking a more constructive stance, building on the important research breakthroughs of the past decade and emphasizing their implementation in practice. As a consequence of an enormous increase in research and policy attention surrounding ecosystem services, Theme C is also particularly relevant in the densely populated Mediterranean area. Finally, Theme D draws on the vast research and practical experience of the European Forest Institute and other leading global players to consider the unique value and positioning of Mediterranean wood and non-wood resources as an opportunity for the forest-based bioeconomy.

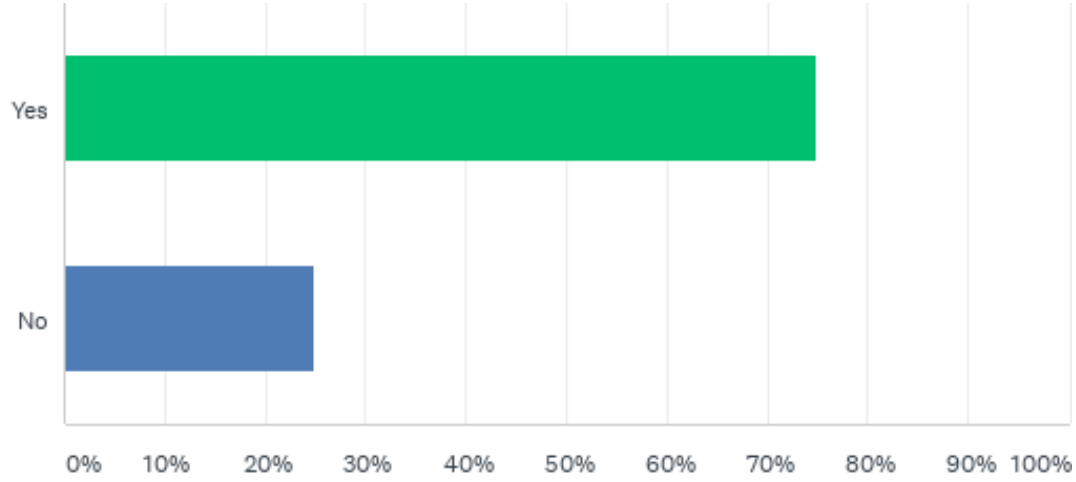
While these themes and the process of the developing them provide a strong jumping off point for the new MFRA 2021-2030, the results from this survey, as explored below, as well as planned seminars and opportunities for contribution throughout 2021 will also provide key inputs for the final version of these themes.

Survey respondents reflected on these themes, in general confirming that they were well chosen. Theme B, on resilience in the face of disturbances, was consistently ranked highly by respondents who found it both of very high relevance and interest to their institutions. Themes A, C, and D were also indicated by respondents to be of relevance and interest to their institutions. The individuals surveyed reported that their institutions had the most experience in Themes A, B, and C, with Theme D, on social and business innovations, representing a new area for fruitful research.

Additional research themes

A clear majority of the respondents indicated that there were additional key research areas that were not addressed by the four proposed themes (figure XX).

Do you see other important research needs for the next decade not addressed by these 4 new themes?



In their reflections on the successes of MFRA 2011-2020, participants already identified some thematic areas from the previous period that they felt warranted continued attention: both because of the progress that was made over the past decade thanks to the MFRA spotlight, and the magnitude of the work that still needs to be done. In particular, the experts surveyed felt that additional connections were needed to bridge scientific achievements in forest fire research with actual fire management actions, and that more attention should be placed on promoting ecosystem services academically and politically.

Further to these pending efforts related to the thematic focus areas of MFRA 2010-2020, survey respondents were given the opportunity to suggest additional research themes for consideration in the MFRA 2021-2030. Their contributions fall roughly into four broader categories: climate change, urban forestry, governance, and participatory science. Each are explored in more detail below.

Climate change

While significant emphasis was placed on climate change in MFRA 2010-2020, and it is highly visible across the proposed thematic areas for MFRA 2021-2030 (particularly in the highly-ranked Theme B), respondents were not satisfied that there was a sufficient spotlight on climate issues in the new proposed themes. One specific area they felt warranted further attention are the synergies and trade-offs between mitigation and adaptation strategies, especially to avoid unintended conflicts when strategies are actually implemented. A similar, large-scale focus area suggested by a respondent is studying climate impacts through the effects of climate variability on ecosystem processes, rather than on the effects of average annual changes. Though these suggestions follow a more semantic tone, perhaps there is room to incorporate the sense of urgency and desire for a more explicit climate focus in the proposed thematic areas.

Urban forestry

An area that was also mentioned by respondents as a high point in the results of the previous MFRA, urban forestry emerged as the most common suggestion from respondents to be included in the new MFRA. In particular, respondents feel urgent research is needed regarding the role of urban forestry in improving livability of Mediterranean cities, and further in supporting resilient landscapes beyond the urban borders. In the wording of their suggestions, such as framing urban forestry as "the anchor for the citizens of tomorrow", respondents invoke the language and imagery of biocities and the bioeconomy, implying a potential link to the less popular Theme D. Strengthening Theme D with an explicit inclusion of the high-demand concept of urban forestry could improve its coverage and reception.

Governance

Within the broader topic of governance, most respondents were concerned with issues of quality and legality in the international timber trade. This extended not only to improved systems for quality assurance and legality tracking, but also specifically combatting illegal activities, such as logging and arson. Though these particular governance issues could be made to fit under Theme B, relating to resilience and forest disturbances, another suggestion by one respondent solidifies a specific interest in Mediterranean forest governance that is apparently missing from the current proposed themes. The respondent references a problem specific to Mediterranean forests: "as they are not part of national forestry priorities, investments for their adaptation to change are not accompanied by financial measures: some Mediterranean forest cover is likely to be really threatened by future droughts and dieback".

Participatory science and stakeholder engagement

Last in order here, but not least in importance to respondents, is the issue of participatory science, training, and involvement of communities and forest owners in science and management. While not particularly well suited, perhaps, to being a stand-alone thematic area, this transversal point applies to, and could be explicitly incorporated into the broader strategic approach of MFRA 2021-2030. In particular, the experts who participated in the survey felt that improved support for, engagement with, and participation of local communities, including forest owners, in climate and other disturbance-related planning, including in tools for future scenario modelling, was a growing, but still urgent, area of focus.

While the respondents felt the four proposed themes did not address the additional key research areas they have suggested in the four categories above, some of their contributions do fit clearly within the four proposed themes. However, their contributions capture important focus areas within those themes, and therefore we have recorded and included these suggestions below, as potential sub-topics under the already proposed themes.

THEME A: Conservation and management of biodiversity and forest genetic resources

- Indicators of conservation status of ecosystems
- Managing wildlife and livestock to ameliorate forest biodiversity and control human - forest interaction
- Forest ecosystems as corridors for biodiversity hotspots connection
- Managing forest resources to control Invasive Alien Species (IAS) to maintain forest biodiversity

- İnventory of forest biodiversity and building biodiversity database for effective knowledge management

THEME B: Forest resilience in a context of global change related forest disturbances

- Adaptation of Mediterranean trees and forests in the context of global environmental change and modification of disturbance regimes and their associated risks
- Compound/clustered extreme events (i.e. concurrent and/or consecutive). Furthermore, more attention should be given to synergies among disturbances (e.g. climate effects on pests could have synergistic effects with drought). Note that feedbacks between disturbances are likely to be dependent on the sequence of climatic events that take place.
- Interactive effects of climate change and air pollution on Mediterranean ecosystems
- Post-fire soil erosion mitigation and landscape change
- Crisis prevention and management
- Benchmarking the composition and history of forest ecosystems to determine, for example, the need/priority for rehabilitation and afforestation of degraded forest ecosystems.

THEME C: Forest management addressing trade-offs and synergies between multiple ecosystem services

- Biodiversity-Ecosystem Services relationships, with special focus on forest soils (transversal research theme)
- Nexus - Integrated forest and water management at catchment level, from snow-capped mountains to river estuaries
- Characterization (identification, quantification and valuation) of ecosystem services
- Development of versatile DSS (e.g., web-based, virtual, game management) to prepare multiple use forest management plans

THEME D: Social and business innovations and policy instruments to implement the Mediterranean forest-based bioeconomy

- Wood and Mediterranean NWFP product technology & biorefineries for the forest-based bioeconomy