Lebanon's National Blueprint for a Sustainable Forest Biomass:
promoting renewable energy and forest stewardship

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Developed by:
Biodiversity Program
Institute of the Environment – University of Balamand – Lebanon

In partnership with:
The University of Lleida - Spain

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Foreword

The "National Bioenergy Strategy for Lebanon", published by the Ministry of Energy and Water and the UNDP back in 2012, indicated that the most promising biomass resource for the country is that of sustainably harvested forestry and agricultural residues. The newly published National Renewable Energy Action Plan (NREAP) 2016 – 2020 has set a target of bioenergy for heating at 166.66 ktoe by 2020.

In order to reach these targets, we must support and monitor all stages of biomass production, ensuring first and foremost that the harvesting of biomass from forestry residues or from agricultural residues is done in a sustainable manner. It is also important to note that harvesting of biomass from forestry residues has the added benefits of reducing fire risks and creating rural employment, and harvesting of biomass from agricultural residues may increase revenues for farmers. We must make sure that the technologies that are set up to transform these residues are up to the required technical and environmental specifications.

The Ministry of Energy and Water is committed to focus not only on electricity production from bioenergy, but also on heating as well in order to increase our energy security and provide affordable and sustainable heating options for rural communities. At this stage, and thanks to the pilot projects implemented by the UNDP CEDRO, the country is gathering pace and momentum towards achieving a more sustainable energy system. We are moving forward to understand better the national and natural resources, which may be used to satisfy our growing energy needs.

Arthur Nazarian
Minister of Energy and Water

Foreword

The strategy of the Ministry of Agriculture for the years 2015–2019 included the objective of improving the good governance and sustainable use of natural resources through:

1) Adopting good governance and promoting sustainable use of forests, and;

2) Implementing Lebanon's forest fire management Strategy and rationalizing the harvest and investment of wood and non-wood forest products.

In addition to establishing an area of forests and rangelands on which a plan for sustainable management was foreseen.

Lebanon's National Strategy for forest fire management (Decision No. 52) comprised a strategic objective on modifying fire risk through a number of means (e.g., encouragement of sustainable fuel wood collection coupled with incentives for farmers/herders not to burn crop residue and pastures). Also, it addressed the need to develop preventive silviculture and fuel management aiming at reducing the highly flammable biomass and management of the forests to increase their resistance to fires (or reduce their susceptibility to fires). This includes but is not limited to grubbing and pruning, tree thinning, brushwood crushing, prescribed burning, controlled grazing and species selection.

Lebanon's National Forest Program (2015-2025) operational objective 5 highlighted the importance of developing an action plan to support small entrepreneurs and small forest enterprises through the development of value chains in wood (Activity 5.1) in addition to putting in place a sustainable management plan for the development of the socio-economic values of wood (Activity 5.3).

To this end, I hope that this publication will serve the purpose of further promoting the sustainable harvest and use of biomass from forestry and agricultural residues such that our forests are further protected from risks of fires and in order to increase local sources of employment and revenue.

Akram Chehayeb
Minister of Agriculture

Foreword

The European Union gladly contributed to this innovative project, which looked into biomass briquetting from forest residues in Lebanon. The project provided framework for both analysis and experimentation on this renewable energy source – which is still rarely used in the country. The strong leadership of the CEDRO IV project team and the Ministry of Energy and Water in this pilot operation has led to interesting and promising conclusions that are described in this report.

In the European Union we did similar exercises some years ago, and it was widely acknowledged that increasing the use of biomass in the EU could not only help diversify Europe's energy supply, but could also create substantial growth and jobs while lowering greenhouse gas emissions. We look forward to witnessing a sustainable development of this promising source of energy in Lebanon, and its direct and indirect positive effects on Lebanon' socio-economic situation.

Ambassador Christina Lassen

Head of the Delegation of the European Union to Lebanon

Foreword

The present set of reports on the potential use of bioenergy in Lebanon was prepared by the "Community Efficiency and Renewable Energy Demonstration" (CEDRO) project, which supports the country's efforts towards a national sustainable energy strategy. CEDRO, active in Lebanon since 2007, is funded by the European Union and implemented by UNDP.

Bioenergy which originates from forest and agricultural residues can be fabricated into various forms such as briquettes or logs, and has the potential to be a viable resource for household heating and cooking. Using bioenergy reduces dependence on highly polluting fossil fuels and also plays a vital role in reducing illegal logging. With the increasing risks of forest fires posed by climate change, establishing a value chain for the sustainable harvesting of forest residues for briquette production also serves to reduce this risk. Finally, the production of bioenergy provides sources of rural income to local communities and generates employment opportunities since manufacturing includes labour intensive tasks such as pruning of trees and collection of biomaterial.

Biomass briquette production has a significant growth potential both in residential and industrial markets. Its environmental benefits include sustainable forest management, neutral carbon dioxide emissions balance, and low sulphur emissions. Its other advantages include a high calorific fraction, significant moisture content, and lower ash content. In general, briquettes are an ideal fuel for low consumptions where the higher cost of the fuel is balanced out by the lower investment cost of the simplified heating technologies.

The reports are based on practical knowledge gained by the CEDRO project during the implementation of two pilot projects that introduced systems for briquette production. They provide real-life tools and guidelines on how to manage forest resources in the Lebanese context, how to design and construct briquetting machines, and how to manage the systems. UNDP hopes that these publications can support in expanding the use of such environmentally-friendly technologies and promoting the uptake of sustainable energy resources in Lebanon.

Philippe Lazzarini
UNDP Resident Representative

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List of Acronyms

AFD	Agence Française de Développement
BAT	Best Technology Available
BMP	Best management practice
BP	Biodiversity Program
DBH	Diameter at Breast Height
IOE	Institute of the Environment
UOB	University of Balamand
CBL	Central Bank of Lebanon
CEDRO	Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon
CIDA	Canadian International Development Agency
CDM	Clean Development Mechanism
CHP	Combined Heat and Power plants
CDR	Council for Development and Reconstruction
COM	Council Of Ministers
CTFC	Forest Sciences Centre of Catalonia
DEM	Digital Elevation Model
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment
FFEM	French Global Environment Facility
FTE	Full-time equivalents
GIS	Geographic Information System
GiZ	German International Cooperation
GPS	Global Positioning System
ILO	International Labor Organization
IPCC	Intergovernmental Panel on Climate Change
IUFRO	International Union of Forest Research Organizations
LCEC	Lebanese Center for Energy Conservation
LP	Land features, physiographic limits and infrastructures
LRI	Lebanon Reforestation Initiative
MEW	Ministry of Energy and Water
MOA	Ministry of Agriculture
MOE	Ministry of Environment
MOF	Ministry of Finance
MU	Management Unit
NEEREA	National Energy Efficiency and Renewable Energy Action

NFP	National Forest Programme
NGO	Non-Governmental Organization
NCSR	National Council for Scientific Research
NFBP	National Forest Biomass Blueprint
OWL	Other Wooded Land
R&D	Research and Development
RDNRD	Rural Development and Natural Resources Directorate
SAF	Society of American Foresters
SC	Species Composition
SI	Site Index
SME	Small and Medium-sized Enterprises
SS	Stands of Special interest
ST	Stand structure
SWOT	Strengths, Weaknesses, Opportunities and Threats
TC	Tree Cover
UNDP	United Nations Development Programme
USAID	US Agency for International Development
USDA	US Department of Agriculture

Executive summary

Lebanon possesses an acceptable diversity of forest types, representing a wide variety of ecological conditions and managed for an array of social values and objectives. The preservation of Lebanon's forests for the future requires stewardship, as no forest anywhere in the world is free from external factors, either natural as climate, or anthropic as local and global markets. Forestry provides the technical tools for forest preservation when intervention is needed.

Forest biomass (i.e. the dry weight of living organisms) is an important measure of ecosystem productivity. It is used in quantifying the role of forests in the carbon cycle and the potential of wood products for energy production. In this context, a sustainable forest management and its main tool -extraction of fellings and pruning residues from the forest biomass - including the utilization of woody biomass have numerous direct and indirect social, economic, and ecological benefits. In brief, these may range from ecological goals such as target reconstruction of original ecosystem composition in flora and fauna, limiting forest fire hazard (i.e. reducing fuel density by exploiting and properly processing biomass residues), or promoting a healthy forested ecosystem by controlling pests, to socioeconomic goals related to the provision of renewable fuel for clean energy, creation of economic opportunities in the community, lowering greenhouse gas emissions over fossil fuels, the improvement of the living tree component of the standing volume (growing stock), landscape design, or raised production of non-wood forest products, among many others.

Unsuitable forest management plans or unsustainable harvesting of forest biomass, however, can pose a threat to forest values, including biodiversity, recreation, water quality, and wildlife habitat. Such unsuitable plans can also deplete the very own forest goods/products harvested and used by society. Accordingly, guidelines including best management practices (BMPs) for developing forest inventories, and consequently, forest management and harvesting plans, are necessary tools to ensure the sustainable use of forest biomass within a multifunctional set of goals. The rules for sustainability are clear: 1) harvests can never exceed forest growth; hence the importance of the inventory, 2) thinning may be conducted to reduce competition between trees or improve forest condition only under technical guidance, and 3) felling must be inexorably linked to regeneration, preferably natural regeneration, leading to a bio-diverse and ecologically stable forest capable of fulfilling societal demands.

Accordingly, this National Forest Biomass Blueprint (NFBP) has two objectives, namely to 1) lay out strategic objectives that will help realize the full potential of Lebanon's forest biomass , and 2) provide necessary guidelines for developing forests inventories, management and harvesting plans towards sustainably meeting those objectives.

Background information

Chapter 1 presents background information on sustainable forest biomass management and use of bioenergy from forest biomass.

Numerous adaptive Mediterranean forest and landscape management strategies and interventions are recommended to enhance long-term carbon storage and further mitigate against climate change. Consequently, undertaking site-specific silvicultural practices such as selective logging, dead wood removal and thinning are expected to reduce stand density, decrease competition for water, activate biomass production, and enhance resistance and resilience to disturbances (e.g. fire and pests). Most importantly, national incentives must be made available to improve the economic feasibility of forest biomass projects. National policies have an important role to play in promoting research and furthering the science of sustainable forest biomass management. Also, funding and investments in research and development programs, and resource assessments, are essential to realizing the full potential of woody biomass as a renewable, low-carbon energy source.

The literature provided insight into the importance of developing bioenergy from forest biomass residues. However, the lack of scientific and practical knowledge about many aspects of using forest biomass for energy remains of major concerns to decision-makers. Also, several barriers to wood bioenergy development remain, including cost, market formation, creating synergies with agriculture and the energy sector, managing competition in terms of resource uses and markets, and laws and regulations. In this context, it would be important to take advantage of existing knowledge and experience in a number of countries, mainly European Mediterranean countries, which have already been using forest biomass as a source for bioenergy.

The forest biomass sector in Lebanon

Chapter 2 discusses the National context of the forest biomass sector in Lebanon including advantages of woody biomass utilization. It presents relevant institutional arrangement and existing laws, regulations, and strategies. Forest resources assessment and bioenergy potential from forest biomass are also presented.

Increasingly, Lebanon's forests, which include remnants of valuable broad-leaved trees, conifer forests and evergreen trees that cover the Lebanese mountains in patches, are exposed to degradation due to quarries, urbanization, pests and diseases, fires, wars, human neglect, improper management, and poor law enforcement. More specifically, increasing threats of forest fires have brought attention to the hazardous fuel buildup in the forest and opportunities to reduce this risk. Consequently, tree pruning and thinning in Lebanese forests can provide relatively large volumes of woody biomass especially from high fire hazard forests, therefore, reducing fire hazard in these areas. Principal sources for woody biomass in Lebanon could be harvest residues, small diameter trees, trees removed for renovation of degraded stands, trees damaged by wildfire, insects, diseases, and short rotation woody crops.

In Lebanon, several cross cutting responsibilities exist among different governmental institutions that deal with forestry, forest fire fighting, protection, law enforcement, and other forest related issues. However, the Ministry of Agriculture (MOA) through its Rural Development and Natural Resources Directorate (RDNRD) is the official body in charge of the forestry section in Lebanon. Yet, there is a need to establish a coordination mechanism among all these entities in order to ensure sustainable and efficient use of forest biomass.

Until present, Lebanon has two forest laws, namely the Forest Code of 1949 that provides the basis for the management of forests by MOA, and the Law 85 for the protection of forests (amended by law 558 in 1996). Also, MOA signed a decision (433/1 dated 30/8/2010) in respect of "regulating forest and other wooded land harvesting". Lebanon adopted in 2009 a National Strategy for forest fire management (Decision 52 dated 13/5/2009). Yet, Lebanon lacks initially law enforcement and the implementation of a National Forest Policy or Programme (NFP). Most importantly, the current legal framework does not allow cuttings in Pinus brutia forests. In contrast these types of forests should be allowed to be pruned and thinned based on scientific forest management and harvesting plans to reduce fire hazard in these forests and to promote economic income to local communities.

According to the Forest Resources Assessment Report of FAO in 2010, Lebanese forests cover about 137,000 ha (13% of the territory) and Other Wooded Land (OWL) covers 106,000 ha (about 10%) of the national territory. The growing stock of commercial species in Lebanon (in 2010) was estimated at 1.458 million cubic meters in forest lands and 0.152 million cubic meters in OWL. Also, the total biomass (including above-ground and below-ground biomass) was estimated in 2010 at 3.688 million metric tonnes oven-dry weight in forest lands and 0.397 million metric tonnes oven-dry weight in OWL. Industrial wood removal is still prohibited and not applicable to Lebanon. The only industrial activity is artisanal handicraft, which quantities are negligible and difficult to estimate and valuate. Woodfuel removals (including charcoal and fuel wood removed for energy production purposes, regardless whether for industrial, commercial or domestic use) were estimated in 2005 at 18200 m3. Overall, the report noted an increasing trend of employment in primary production of woods with the higher demand on fuel wood and pine nuts, especially in deprived areas. However there was a decreasing trend of paid employment/self-employment since people are not keen to work in forestry activities that are usually less remunerating than other type of employment. Accordingly, proper incentives to local community groups and individuals can help in promoting activities in sustainable forestry.

In reference to the National Bioenergy Strategy for Lebanon, forest wood biomass stream presents an interesting theoretical potential. The total primary energy potential of woody biomass and fellings ranges between 1952 and 2510 TJ/year, which is a relatively significant amount. However, this potential is considerably difficult to develop for several reasons: forests are located in the mountains where the first preoccupations are reforestation and biodiversity protection, and many exploitable forests are privately-owned, therefore, inducing some limitations and challenges. Also, "sustainable harvesting" is difficult to establish with the outdated laws and weak law enforcement. Accordingly, the introduction of new legislation or policies to practically stimulate future investments in forest biomass resources is needed.

Forest biomass strategic objectives

Chapter 3 presents the strategic forest biomass objectives. The main identified strategic objectives that will help realize the full potential of Lebanon's forest biomass includes 1) support Research and Development (R&D) investment that will provide foundation for the future management of Lebanon's forest biomass, 2) promote necessary policy tools, reforms in legislation, and law enforcement, and 3) identify and support opportunities for the development of forest biomass.

In general, Research, Development, and Outreach in forest biomass could represent a thriving area of research and development in the private sector as well as in universities and governmental agencies. It would be essential; however, to be assured through an ongoing commitment to research that forest biomass use will not conflict with conservation and stewardship goals.

Key activities that can help in promoting necessary policy tools, reforms in legislation, and law enforcement are mainly organized into four pillars: capacity building, policy, technology transfer, and market development. Eventually, the identification of support opportunities for the development of forest biomass would require pooling needed resources (i.e. financial mechanisms), and knowledge and expertise (i.e. building collaboration and supporting the establishment of public-private partnerships through the involvement of national and local stakeholders).

Overall, the forest biomass strategic objectives are expected to engage a large number of stakeholders; however, MOA would have lead responsibility for Blueprint coordination. This effort would include a consultation process to be conducted at the national level, engaging policymakers, forest scientists and managers, private sector, and the civil society.

Management and implementation

Chapter 4 discusses the legal and technical frameworks for management and implementation of forest biomass activities and projects and describes the usual process of forest management planning. More specifically, developing forest inventories, management plans, and harvesting plans are discussed.

Overall, the ministerial Decision 433/1 dated 30/8/2010 comes in line to a certain extent with the Forest Law and it is expected that the required permits for harvesting and thinning can help in preventing abuses in the forestry sector. However, Decision 433/1 allows pruning between September 15 and April 15 of each year, while tree burgeoning and flowering can start as early as mid-March, especially in areas below 500 meters above sea level. Accordingly, pruning should not exceed, in principle, March 15 of each year especially under a changing climate scenario. Legislation, therefore, needs to be updated in response to a changing climate and in line with needs on the ground based on the principle of sustainable forest management and conservation of ecosystems.

Again, working resinous trees such as Pinus brutia should be regulated and organized because they are considered as useful investments for locals. Besides, large and dense Pinus brutia forests

represent a favorable environment for fires, and the failure to regulate maintenance of the vegetation cover in these forests will not help in preventing relatively large scale fires. Accordingly, Pinus brutia forests should be allowed to be pruned and thinned based on scientific forest management and harvesting plans to reduce fire hazard in these forests and to promote economic income to local communities. Tools such as "FireLab" and the best practice guidelines of "Firewise-Lebanon" can be used to extract needed information about managing fire risk (including forest fuel) at the local level.

No plans have been developed to manage and protect forests that are directly owned by the State and by local community groups. In this regard, proper forest inventories, management plans and harvesting plans should be developed for these forests to ensure their sustainability. Also, the ongoing efforts to develop a national forest policy need to be finalized in order to ensure the sustainability of forests and to have forests able to perform their ecological role in light of climate change. In addition, a national forest policy will help in improved protection and conservation of existing forests in response to an increasing demand for forest wood and non-wood products.

Currently, pruning permits that are given in accordance with the existing regulations are not properly monitored; in addition, fines are not properly enforced. Although theoretically fines for illegal pruning are high, violators often do not pay these fines and are not legally pursued; therefore, the fining system is not a deterrent. Most importantly, human, financial, and technical resources of the MOA should be improved in order to deal efficiently with suppressing irregularities and simultaneously conducting all tasks related to overseeing, controlling and monitoring of works in forests.

Finally, forest management planning is a process that should be addressed at the level of all existing forested areas in Lebanon, especially public forests (e.g. State and communal forests). Accordingly, descriptions for developing a generic forest inventory scheme, forest management plan, and forest harvest plan are presented in this study. More specifically:

- Sustainable management of forested areas requires a more precise information system and a constant monitoring of the quantity and quality (e.g. forest stands, species composition) of forest resources. Specific forest resources information on wood volumes and growth is needed at the forest management unit level in order to determine sustainable yields of wood production. In this context, a forest inventory is considered as initial stage necessary to cover the data gaps and to develop national forest management plans
- A forest management plan is an indispensable part of a forest management system and should regulate protection, inventory, growth & yield determination, silviculture, harvesting, and other forest operations, being foremost the planning, execution and monitoring of forest regeneration and stand development prescriptions over time. Also, a forest management plan is required to provide continuity in managerial operations over time, to formalize administrative arrangements and to provide a basis for monitoring forest activities.
- A strategic harvest plan explains why, where, when and what type of harvesting is proposed. Harvest planning cannot be separated from management planning, as both must be done simultaneously by an interdisciplinary planning team. Informative maps and a written plan are elements of a good strategic harvest plan, as detailed year-by-year scheduling.

Introductory notes

It is very well recognized in the literature that woody biomass from forest management is a renewable, low-carbon feedstock that can substitute for fossil fuels in the production of energy and other products. In this context, the appropriate management of woody biomass is considered as a potentially important tool supporting national efforts in reducing greenhouse gas emissions (Caputo 2009). Accordingly, incentives such as markets for forest biomass residues, small diameter trees, and other low-value forest products can add value to working forests, help provide financial alternatives to land clearing and development, and create incentives for investing in sustainable forest management.

It is essential though to keep in mind that forest thinning and removal of small-diameter and low value trees are integral parts of forest management for a number of values and objectives — biodiversity conservation, ecological restoration, wildfire prevention, and stand improvement. Yet, there is also the potential for increased demand to drive unsustainable levels of harvesting, with negative consequences for biodiversity, soil, and water conservation. Consequently, national policies and guidelines should strive to ensure the sustainability of woody biomass harvesting in concert with forest stewardship.

Context and scope of work

Building upon the inputs of the "Forest inventory and management plans of Bkessine and Andket forests in Lebanon" report within the framework of "provision of professional services for the Inventory Development, Management Plans for Two Forests in Lebanon" submitted to UNDP Lebanon in response to "LEB/CO RFP/122/14", this document sets forth a Blueprint for Action in the field of Lebanon's sustainable forest biomass management for promoting renewable energy and forest stewardship for the period 2016 to 2026. The National Forest Biomass Blueprint (NFBP) has two objectives, namely to:

1. lay out strategic objectives that will help realize the full potential of Lebanon's forest biomass,
2. provide necessary guidelines for developing forests inventories, management and harvesting plans towards meeting those objectives.

CHAPTER 1

BACKGROUND INFORMATION

Forest biomass (i.e. the dry weight of living organisms) is an important measure of ecosystem productivity (FAO 2010a, 2101b). It is used in quantifying the role of forests in the carbon cycle and the potential of woody biomass for energy production. Table 1 shows the estimated total forest biomass in selected countries of the Mediterranean in 2010 (FAO 2013).

However, an increase in woody biomass is not always the result of good forest management. It can also be a consequence of the abandonment of forests and rural areas, especially in northern and eastern Mediterranean countries, and can increase the risk of wildfire. In the Mediterranean region, forest fire causes severe damage, and biomass reduction may be an appropriate treatment to decrease the risk of wildfire.

Wildfires, forest health, rural development, and to a certain extent energy security are emerging as new driving forces for bioenergy. It is well established in the literature that forests can serve as energy sources while offering a variety of goods and services, including wood and non-wood products and environmental services (e.g. protection of wildlife habitat and recreation areas).
Nevertheless, several barriers to wood bioenergy development remain, including cost, market formation, creating synergies with agriculture and the energy sector, managing competition in terms of resource uses and markets, and laws and regulations.

Table 1: Estimated total forest biomass in countries of the Mediterranean in 2010

Country	Above-ground biomass (Million tonnes)	Below ground biomass
Cyprus	4.6	1.5
France	1979	564
Greece	132	37
Italy	952.2	234.8
Lebanon	2.9	0.8
Spain	669.8	227.7
Tunisia	14	4.9

Sustainable forest biomass management

Biomass harvesting with the absence of proper forest management and harvesting plans can pose a great risk to a number of forest values, including biodiversity, recreation, water quality, and wildlife habitat. Accordingly, guidelines including best management practices (BMPs) for developing forest inventories, and consequently, forest management and harvesting plans, are widely seen as being important tools to ensure sustainable use of forest biomass (Robertson et al. 2008).

General and detailed forest inventories, management plans, harvesting guidelines, and collaborative decision making are important tools for developing creative and sustainable management directives, as well as ensuring that biomass harvesting will contribute to maximizing the full spectrum of ecological and social values that forests can provide.

Despite the many benefits of woody biomass, the costs associated with harvesting, transporting, storing, and utilizing the material often exceed its value on the energy market. National incentives must be made available to improve the economic feasibility of forest biomass projects. National policies have an important role to play in promoting research and furthering the science of sustainable forest biomass management. Also, funding and investments in research and development programs, and resource assessments, are essential to realizing the full potential of woody biomass as a renewable, low-carbon energy source. Such investments will help ensuring that woody biomass utilization will contribute to healthy and diverse forest ecosystems.

Bioenergy from forest biomass

In addition to the use of forest biomass for heating and cooking, electricity generation (depending of the type of forests and national circumstances) is another way of reducing greenhouse gas emissions by substituting for the use of fossil fuels, for which the carbon footprint is much higher – as long as the forest biomass is derived from sustainably managed forests and efficient stoves, boilers and cogeneration systems (e.g. wood gasification for generation of electricity and heat) are used. In some cases, these emissions reductions are eligible for carbon credits, making such approaches more economically attractive (FAO 2013). The carbon footprint of biomass is generally between 3% and 10% compared to fossil fuels such as diesel. In addition the use of wood for heat produces lower emissions of sulphur and nitrogen oxides than diesel (Encinas et al. 2015).

The literature provided insight into the importance of developing bioenergy from forest biomass residues (Evans and Perschel 2009, Kelty et al. 2008). Sustainability is considered to be an important issue for an overwhelming majority of stakeholders. In this context, it is of highest importance that the use of forest biomass does not adversely impact ecosystem integrity, biodiversity, forest soils, or water resources. Accordingly, forest biomass must be developed as a positive tool for achieving forest stewardship objectives such as habitat management, hazardous fuels reduction, forest restoration and other activities intended to improve forest structure or ecological function (Caputo 2009). Also, it is crucial that the use of forest biomass does not impair the ability of forested landscapes to sequester carbon or result in substantial carbon losses from standing biomass or forest soils. In this context, science-based standards are seen as a fundamental component of any strategy to ensure truly sustainable use of forest biomass.

According to GAO (2006), the real or perceived inability to harvest biomass cost-effectively is seen by many stakeholders as the biggest barrier to greater use of bioenergy. There are, however, quite a number of examples of projects where biomass harvesting has proven cost-effective (Han et al. 2008, Arnosti et al. 2008). These have tended to be projects where haul distances were short, operating conditions were ideal, appropriate harvesting equipment was available, and in which biomass was being harvested simultaneously with higher value wood products. National and local incentives for renewable energy and forest restoration serve an important role in improving the competitiveness of energy from forest biomass. Incentives such as grants to municipalities owning communal forested lands can reduce overall costs. Such incentives can help correct externalities and provide for public goods that are not provided for in the current marketplace, such as climate change mitigation and forest health (Caputo 2009).

Yet, the lack of scientific and practical knowledge about many aspects of using forest biomass for energy remains of major concern to forest management decision-makers (Caputo 2009). There is a large and well-founded body of knowledge surrounding forest management and ecology, but information is thin on many issues particular to biomass utilization (Hacker 2005). For instance, there have been comparatively few studies on how increased removal of small-diameter trees could impact wildlife habitat, soil structure, or nutrient cycling. There is strong agreement that research efforts to understand these impacts must be expanded in the near future. Until then, there is a debate among stakeholders whether or not to expand bioenergy capacity in the absence of complete scientific knowledge. However, it is argued that we know enough about basic sustainable forest management to move forward, learning and refining our methods as we progress. It is worth noting that a number of countries, mainly European, have long been using forest biomass as a source for bioenergy (e.g. Spain). Accordingly, it is important to take advantage of their knowledge and experience.

Collaborative projects remain a key opportunity to develop sustainable bioenergy projects that are socially acceptable, economically viable, and promote sustainable stewardship of forest resources. There is no need to say that successful collaborations (i.e. bringing a larger sphere of knowledge, skill, and experience) often result in reduced (or absent) litigation and greater community support.

Background on forest biomass management in the Mediterranean

Mediterranean forests are very vulnerable and fragile to a large number of threats including fires, over-exploitation, deforestation, and degradation (Mitri et al. 2015). At the same time, Mediterranean forest ecosystems are rich in biodiversity, and provide multiple goods and services, which are crucial for the socio-economic development of rural areas (Palahi et al. 2008). Some of the environmental pressures that are facing the Mediterranean region are arising from an increasing number of populations, especially in the South and East Mediterranean, increasing exploitation of natural resources, and intensified natural risks (e.g. forest fires) associated with climate change.

Predicted climate and socio-economic changes will worsen the existing threats on Mediterranean forests. The Mediterranean region is projected to be much drier and hotter than today in the warm seasons (IPCC 2014). Climate change could affect ecosystems in multiple ways, such as by reducing or expanding their extent and distribution, changing the behaviour of species and their interactions, changing the risk of pressures such as fire, diseases and species invasions, and therefore threatening sustainable delivery of forest ecosystem goods and services (Palahi et al. 2008). More precisely, these climatic changes have already caused or contributed to tree mortality across the

Mediterranean region (Bentouati 2008, Chenchouni et al 2008, Semerci et al. 2008) and are having negative impacts on the carbon and water balances of many Mediterranean forests (Martinez-Vilalta et al. 2008, FAO 2010a). The already harsh climatic conditions for forest growth are projected to continue to deteriorate under all the Intergovernmental Panel on Climate Change (IPCC) greenhouse gas emissions scenarios. Such changes in climatic conditions have major implications for the future functioning and sustainability of Mediterranean forest ecosystems (Lindner et al. 2010). Adaptive strategies are required to cope with multiple uncertainties about the impacts of increases in the frequency and intensity of extreme events. Such adaptive strategies include local-scale (e.g. silviculture and forest planning) and large-scale (e.g. land uses and regulations) activities.

A range of management options and forestry practices, supported by empirical and scientific evidence, is available for use in adapting to climate change (FAO 2011, Alcamo 2007). Palahi et al (2008) showed that there is a current need for new Mediterranean forest management planning approaches. These include:

- Moving from wood-based to multi-objective Mediterranean forest planning: the production of non-wood products, the minimization of the risk of fires, the provision of recreation possibilities, the maximization of the quality and quantity of water resources are important objectives that need to be explicitly considered as management objectives in forest planning.
- Moving from a single scale forest planning to a multi-scale landscape planning: the mosaic-like structure of Mediterranean forests, the type of management objectives and the fragmented forest ownership require a multi-scale stand- to landscape forest planning approach.
- Moving from static to adaptive forest planning: in an adaptive planning, decision-makers can adapt their plan according to the changing situations by following adaptive planning instructions on how to react to different changes (e.g. sudden droughts or forest damages from fires).

Also, FAO (2013) recommended in the context of sustainable use of multifunctional Mediterranean forests, numerous adaptive Mediterranean forest and landscape management strategies and interventions, which may require changes in forestry guidelines and visions, to enhance long-term carbon storage and further mitigate climate change. These included, among others:

- Promoting forestation and reforestation activities (using monospecific or diversified stands).
- Restoring degraded soils and managing encroachment.
- Promoting better-adapted trees (e.g. that are tolerant to drought and pests) and modifying tree species composition (e.g. more diversified and resilient stands, multipurpose trees).
- Undertaking certain practices at the landscape and stand scale to reduce forest fire intensity, propagation and damage and to improve ecosystem resilience and recovery and implementing post-fire restoration activities.
- Undertaking site-specific silvicultural practices such as selective logging, dead wood removal and thinning to reduce stand density, decrease competition for water, activate biomass production, and enhance resistance and resilience to disturbances (e.g. fires and pests).
- The situation report on forest biomass use in Mediterranean region (proforbiomed 2012) presented the current situation, problems, and opportunities for the development of the forestry biomass chains in Mediterranean countries. Main conclusions drawn were presented in Table 2.

Table 2: Current situation, problems, and opportunities for the development of the forestry biomass chains in Mediterranean countries

	Objectives/ current situation	Opportunities for exploitation	Challenges and difficulties
Spain (Valencia)	Protection and prevention against forest fires	Thinning, cleaning, commercial exploitation residues, among others A subsidy line to enhance biomass value of forests	Heterogeneity of public and private forest ownership (i.e. lack of economies of scale) Forestry sector is no longer an active generator of jobs and wealth in many rural areas Little active policies derived from a forestry strategy Low presence of forest exploitation companies Low technological development of equipment Lack of a developed market of biomass distribution and instability in product availability in quantity, quality and price Dispersion of information and lack of knowledge transfer High degree of heterogeneity of forest biomass Competition on price with other fuels, including biomass from other regions, countries or continents, High levels of investment, among others

	Objectives/ current situation	Opportunities for exploitation	Challenges and difficulties
Portugal	Managing forest areas in order to produce sustainable goods and servicess	Enterprises with equipment to process and prepare forest residues for use as biomass are emerging	Difficulties in collecting and marketing forest residues Scarcity of hand work in rural areas Lack of a true logistics of biomass collection Difficult physiographic conditions in the region (i.e. requirement of appropriate equipment conceived to collect biomass)
France	Local residents need to be reassured on compatibility of logging with biodiversity and that the wood resource is renewable in the context of forest sustainably managed.	Public forest management plans and private forest management plans allow knowing volumes that will be harvested in the coming years Forest management plans are the guarantee that cuttings have been planned in a sustainable way	Forest management plans exist for public forest but some of them would need to be updated

	Objectives/ current situation	Opportunities for exploitation	Challenges and difficulties
Greece	Economic crisis that forces people to seek cheaper ways to heat their households	Existing companies can occasionally benefit from subsidies addressing the overall improvement of their operation, but not focusing solely on biomass use A specific subsidy to support the establishment and development of companies producing biomass related products, from boilers to pellets, would definitely boost the relevant market and provide multiple added values to the local and regional economies	Difficult morphology of the Greek forest lands (i.e. not any heavy machinery is used for harvesting and cutting the wood biomass) Lack of an organized practice for the management of field residues No special subsidy scheme foreseen for biomass investments
Italy	Forest operations are carefully controlled and restricted, aiming both to timber production and to forest natural regeneration	Large and growing market of pellet stoves for domestic heating. (it will probably continue to drive the demand for pellets in Italy in the forthcoming years) Adoption of quality norms (i.e. UNI/TS 11263:2007 norm based on CEN/TS 14961) and the development of a certification system (as that "Pellet Gold" label11) may create a more favorable background for pellet trade	Discontinuous and fragmented supplies of feedstock for pellet production and large variations in the consumer's price (i.e. an obstacle to the steady development of the pellet industry)

CHAPTER 2

THE FORESTS BIOMASS SECTOR IN LEBANON

National context

Forests cover about 137,000 ha (13% of the territory) and Other Wooded Land (OWL)[1] covers 106,000 ha (about 10%) of the Lebanese territory (MOE/UNDP/ECODIT 2011, FAO 2010b). Ownership of forested lands is almost equally distributed between the private and public sectors and religious orders (MOE/UNDP/UOB 2013, Mitri and El Hajj 2008). Broadleaved forests make up 57% of the total forest cover whereas coniferous forests make up 32%, and the other 11% are mixed forests (Figure 1). Most abundant forests are oak forests covering 52% of total forested areas, while pine forests make up 15% and Juniper about 9%. Cedar and fir forests are much less abundant but nonetheless they represent habitats to many endemic and threatened plant species (MOE/UNDP/ECODIT 2011).

A Land Use / Land Cover map of Lebanon was produced by the Ministry of Environment (MOE) in cooperation with the National Center for Remote Sensing of the National Council for Scientific Research (NCSR) in 2002. This involved the use of satellite remote sensing data acquired in 1998. The final map disaggregated land use and land cover into seven main categories and 23 subcategories. An update version of the 1998 Land Cover / Land Use map was recently completed by the National Council for Scientific Research (NCSR) using satellite remote sensing data acquired in 2005. In 2004, the Council for Development and Reconstruction (CDR) published the National Land Use Master Plan for Lebanon. The Master Plan was approved by the Council Of Ministers (COM) in 2009 (Decree 2366 dated 20/6/2009).

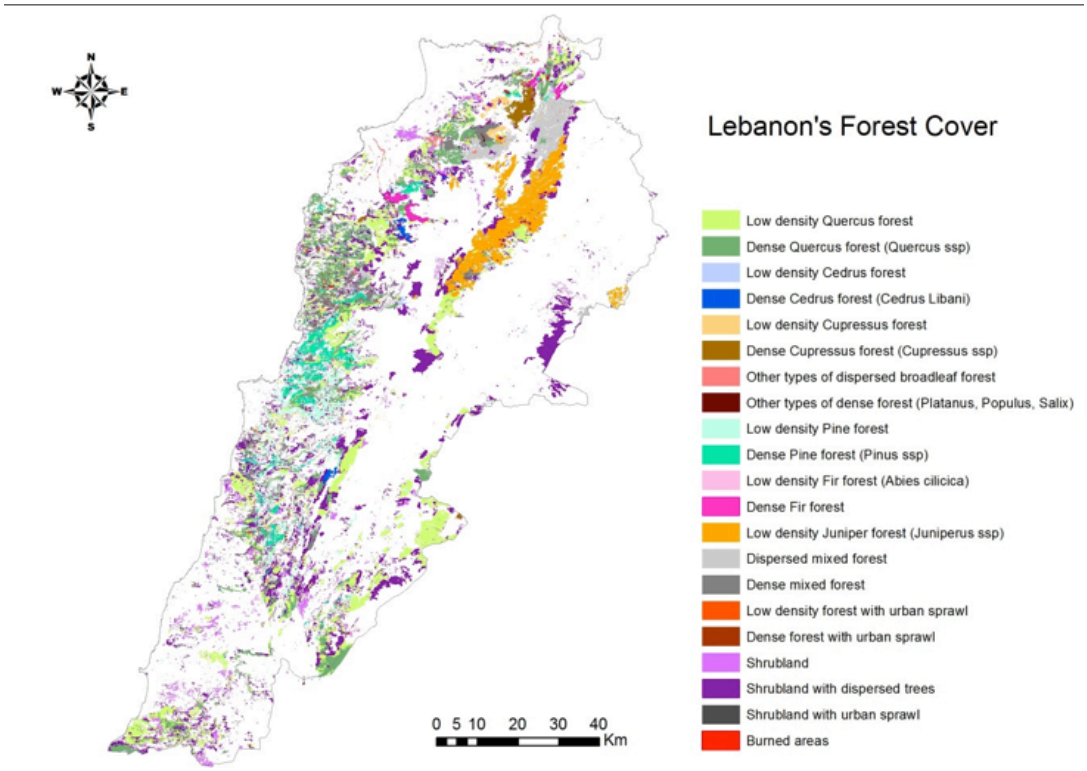


Figure 1. Forest types distribution map of Lebanon 2005

[1] *Forest: Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.*
Other wooded land: Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use. (FAO, 2010)

Forests in Lebanon have undergone a process of continuous degradation that has led to their intense fragmentation, a significant loss of ecological integrity and the increased vulnerability of rural communities that depend on forest resources for survival (Mitri and El Hajj 2008). More specifically, Lebanon's forests, which include remnants of valuable broad-leaved trees, conifer forests and evergreen trees that cover the Lebanese mountains in patches, are increasingly exposed to degradation due to quarries, urbanization, pests and diseases, fires, wars, human neglect, improper management, outdated laws, and poor law enforcement. Like other Euro-Mediterranean countries, fires have been especially damaging Lebanon's forests in recent years, representing one of the most important elements that destroy Lebanon's natural resources. Moreover, the absence of a national forest management policy and the lack of human and technical resources contribute to the degradation of Lebanon's forests (Mitri et al. 2014a, Mitri and El Hajj 2008). The combination of all these threats and facts, in addition to natural environmental conditions, is resulting in overall forest degradation.

Vegetation composition, biomass, and structure mutually depend on climate and fire frequency and intensity. In turn, fire frequency and intensity depend on vegetation biomass, structure, topography and climatic regimes (Mitri et al. 2015, 2014a). As previously noted, changing trends in socio-economic development and land-use have led to a decrease in grazing and in the collection of wood and forest scrub for fuelwood and fodder. As a consequence, there has been a build-up of highly flammable forest litter. This problem is much more serious in the regions where the rural population has abandoned traditional lifestyles (managing large numbers of livestock and gathering great quantities of fuelwood and other products from the forests for domestic use) than it is in the regions where grazing and other forms of forest related activities are still an integral part of the system. Another cause of increase in forest fuels is the shift of population from the rural areas to the cities. As a result, large stretches of marginal farmland, especially in mountain areas, have been left uncultivated and have been colonized by bush and even natural pine groves. However, the large accumulation of fuels often allows fires set for agricultural and tourism purposes to spread out of control and develop unprecedented intensities and severities which increase the difficulty of putting them out (Mitri et al. 2015, 2014a,). Increasing threats of forest fires have brought attention to the hazardous fuel buildup in the forest and opportunities to reduce this risk (Figure 2).

Figure 2. Dense pine forest in Andket in North Lebanon

Fuel is defined here as the live and dead biomass that either contributes to wildfire spread or are consumed by fire. Fuels are usually categorized as live or dead foliage and wood. The Prometheus fuel type classification system (Table 3) was considered to be better adapted to the Mediterranean ecosystem (Lasaponara et al. 2006, Riano et al. 2002) for mapping fuel type in Lebanon. Accordingly, the fuel type map of Lebanon (Figure 3) was produced and the spatial distributions of the fuel characteristics (Figure 4) were assessed (Mitri et al. 2015, 2014a).

Table 3. Fuel type categorization as per the Prometheus fuel type classification

Fuel type	% Coverage	Description
1	Ground fuels (cover > 50%)	Grass
2	Surface fuels (shrub cover > 60%; tree cover < 50%)	Grassland, shrubland (smaller than 0.3-0.6 m and with a high percentage of grassland), and clear-cuts, where slash was not removed.
3	Medium-height shrubs (shrub cover > 60%; tree cover < 50%)	Shrubs between 0.6 and 2.0 m.
4	Tall shrubs (shrub cover > 60%; tree cover <50%)	High shrubs (between 2.0 and 4.0 m) and young trees resulting from natural regeneration or forestation.
5	Tree stands (>4 m) with a clean ground surface (shrub cover < 30%)	The ground fuel was removed either by prescribed burning or by mechanical means. This situation may also occur in closed canopies in which the lack of sunlight inhibits the growth of surface vegetation.
6	Tree stands (>4m) with medium surface fuels (shrub cover > 30%)	The base of the canopies is well above the surface fuel layer (>0.5 m). The fuel consists essentially of small shrubs, grass, litter, and duff.
7	Tree stands (> 4m) with heavy surface fuels (shrub cover >30%)	Stands with a very dense surface fuel layer and with a very small vertical gap to the canopy base (<0.5 m).

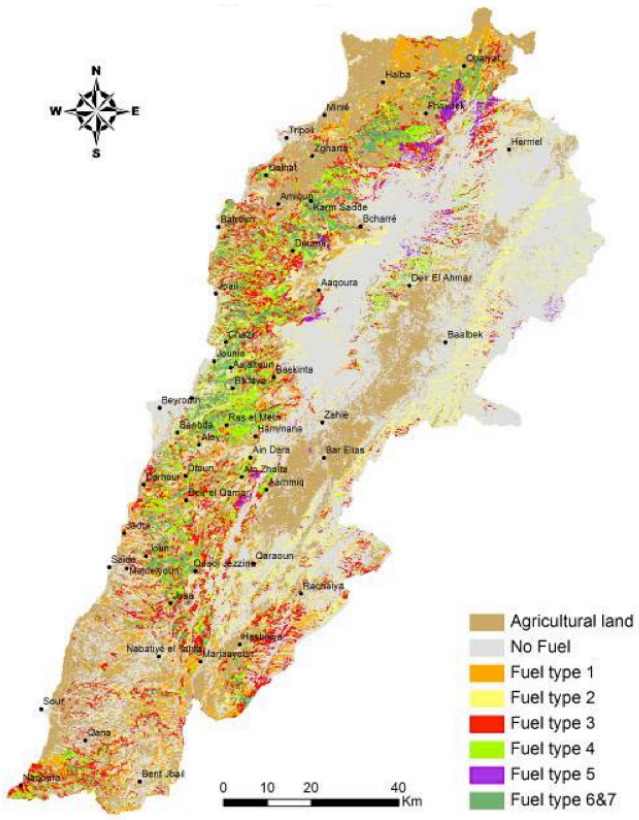


Figure 3. Fuel type map of Lebanon (source: BP-IOE-UOB)

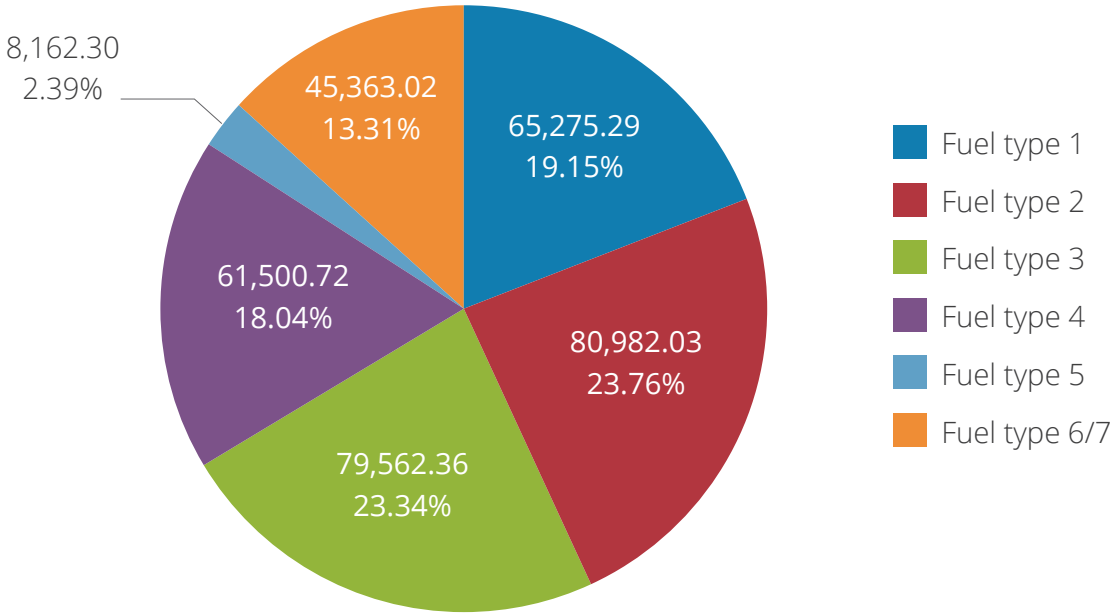


Figure 4. Fuel type distribution per area (ha)

Also, the current wildfire hazard map was produced (Mitri et al. 2015) using a combination of biophysical and climatic data (Figure 5). The wildfire hazard map provided an overview on the hazard distribution across Lebanon and showed that the areas with the highest wildfire potential lie on the western slope of the Lebanon western mountain chain. As a result, it was found that 60% of the Lebanese territory (excluding agricultural and non-vegetated areas) was classified as high fire hazard, while 36% was classified as moderate fire hazard (Figure 6).

Overall, tree pruning and thinning in Lebanese forests can provide relatively large volumes of woody biomass especially from high fire hazard forested areas. Principal sources for woody biomass in Lebanon could be harvest residues, small diameter trees, trees removed for renovation of degraded stands, trees damaged by wildfire, insects and diseases, and short rotation woody crops.

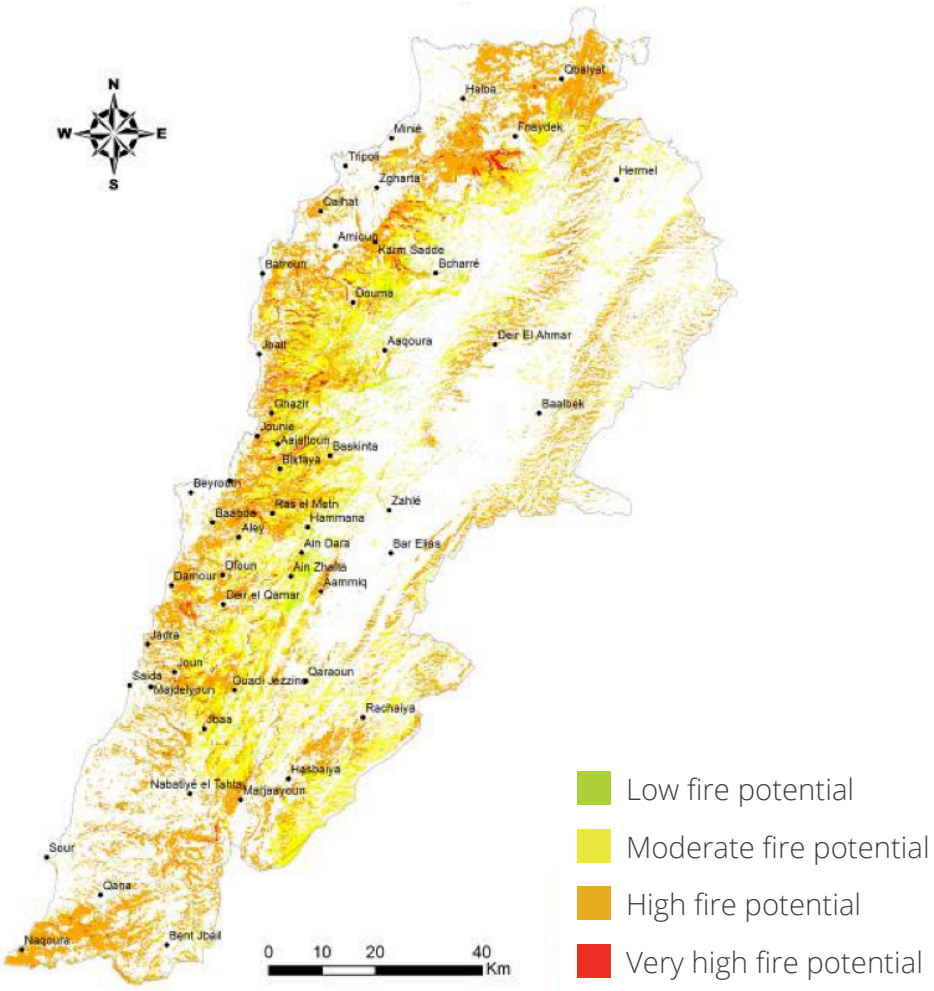


Figure 5. Fuel type distribution per area (ha)

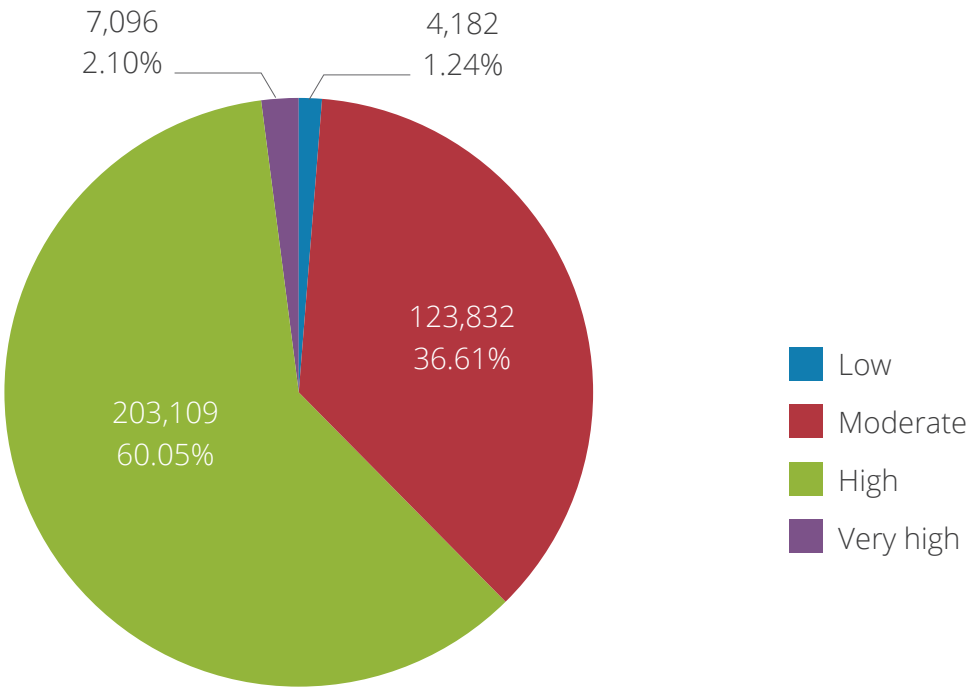


Figure 6. Current fire hazard distribution per area (ha) excluding agricultural and built-up areas

Advantages of woody biomass utilization

A sustainable forest management and its main tool -extraction of fellings and pruning residues from the forest- including the utilization of woody biomass have numerous direct and indirect social, economic, and ecological benefits. In brief, these may range from ecological goals such as target reconstruction ecosystem composition in flora and fauna, limiting forest fire risk (i.e. reducing fuel density by exploiting and properly processing biomass residues), or promoting a healthy forested ecosystem, to socioeconomic goals related to the provision of renewable fuel for clean energy, creation of economic opportunities in the community, lowering greenhouse gas emissions over fossil fuels, the improvement of the living tree component of the standing volume (growing stock), landscape design, or raised production of non-wood forest products, among many others (Figure 7).

Lebanon possesses, however, an acceptable diversity of forest types, representing a wide variety of ecological conditions and managed for an array of social values and objectives. As a consequence, a sound biomass management prescription for one forest could be wholly inappropriate for another. Instead, national and regional policies must promote informed site-level decision making that views biomass harvesting as one tool among many for achieving holistic forest stewardship objectives.

Figure 7. Increasing fire risk from non-treated forest residues

Institutional arrangement

Several cross cutting responsibilities exist between different governmental institutions that deal with forestry, forest fire fighting, protection, law enforcement, and other forest related issues.

However, MOA, particularly the Rural Development and Natural Resources Directorate (RDNRD), is the official body in charge of the forestry sector in Lebanon. The forest guards of MOA as well as the police and municipality guards of the Ministry of Interior and Municipalities are responsible for law enforcement. Until present, the forests guards of the MOA are not allowed to carry arms, therefore facing some difficulties in law enforcement. Human resources involved in the forestry sector include engineers and forest guards at both MOA and the MOE which is also responsible on natural reserves management. Other human resources include staff and volunteers of institutions dealing with law enforcement, firefighting, and research among others.

In principle, tree cutting and charcoal production are conducted after the acquisition of necessary licenses/permits delivered by MOA for private landowners. Exploitation of communal land (including forests, other wooded land and rangeland) for charcoal and pine nut production, fuel wood production, fodder and grazing, is conducted through bids according to tender dossier delivered and supervised by MOA and municipalities. There is also the possibility of establishing contracts with private sector and NGOs to implement forestry activities (e.g. reforestation, forest management, forest protection from insects and diseases, research, studies, and monitoring, among others).

The expenditure in communal land related to forestry activities, accounting 1/3 of the money collected from communal land exploitation, comes under the MOA supervision.

Until present, Lebanon has two forest laws, namely the Forest Code of 1949 that provides the basis for the management of forests by MOA, and the Law 85 for the protection of forests (amended by law 558 in 1996). In addition, Lebanon adopted in 2009 a National Strategy for forest fire management (Decision 52 dated 13/5/2009). Yet, Lebanon lacks a National Forest Policy or Programme (NFP). It was supposed that forestry legislation would be reviewed for 2010-2020 with the implementation of the national forest plan. At this stage, harvesting forests is not allowed in Lebanon except for broadleaved species such as Quercus infectoria and Quercus calliprinos for charcoal production and for wood fuel production. Law 85 prohibits cutting in all conifer forests, including pine forests, which in majority, are state forests, easily exploitable for bioenergy production. Efforts have been deployed by NGOs, in collaboration with MOA to reactivating management rights in public land.

The MOA reviewed some aspects of the forest legislation and cancelled the ban on the production of charcoal to allow a controlled exploitation and stop illegal felling (FAO 2005). This decision was also motivated by the need to reduce the build-up of highly flammable biomass, and alleviate poverty. It may also prevent acts of arson initiated to circumvent the ban on charcoal extraction. The RDNRD has also examined the feasibility of decentralizing forest management, up to a certain degree. Decentralization will lead to a higher involvement of local community groups, municipalities and grassroots organizations. However, such a measure can only be implemented after building the capacities of targeted stakeholders and raising awareness of targeted communities and populations.

A review of relevant laws, regulations, and strategies

Until present, no formal policy exists for forestry in Lebanon; however, MOA has started since 2011 a process of developing an NFP aiming to achieve a sustainable forest management, with the support of the GIZ and of the CTFC (Forest Sciences Centre of Catalonia). The purpose of NFP is to establish workable social, economic and political frameworks for the next 10 years in order to:

- Ensure sustainable management and conservation of forests
- Contribute to the welfare of the present and future generations
- Increase public and private engagement in the conservation of forest resources
- Align with international and national commitments

This programme consisted of a process guided by principles of good governance, stakeholder participation, inter-sectorial co-operation and consultations between government institutions, communities, private sector, knowledge institutions, civil society organizations and NGOs. As a result of this participatory process, the NFP has foreseen four main phases, namely:

- Phase one: The evaluation of forest policies and related strategies (e.g. the forest Law, Law No. 85 dated 7/1/1991, Law No.558 dated 24 July 1997, Decrees and decisions related to forest and medicinal plants, other legislations related to the forest sector such as Law No. 444 dated 29 July 2002 - Law of protection of environment, Strategy for the advancement of the agricultural

sector- Action program 2010-2014, National strategy for forest fire management in Lebanon, National afforestation plan, National strategy to combat desertification, National strategy for biodiversity conservation, etc.).

- Phase two: Participation in multi-stakeholders workshops bringing together the stakeholders of Forest Administration at the field level and all partners in a participatory approach to set the priorities in forest issues.
- Phase three: The preparation of an outline/draft NFP 2015-2025 that will be the subject of discussion and reflection at the national workshop organized by the Ministry of Agriculture.
- Phase Four: Other dedicated meetings with specific stakeholder will follow, in order to discuss the NFP Draft and its action plan.

Until present, the NFP has envisaged a set up for a sustainable management of wood forest product around four pillars:

- Develop forest management plans to ensure sustainability of forest resources (e.g. implement forest management plans at pilot sites with the involvement of local communities, encourage and support the establishment of small sustainable forest related businesses next to forests through awareness, capacity building and small loans, and monitor forest health for diseases outbreaks or pest infestations and provide guidance on treatments and cooperate with universities or research centers on this issue).
- Enforce Law and protect forests from illegal activities such as logging without permits (e.g. equip forest guards adequately and strengthening cooperation with security forces to prosecute offenders, and raise public awareness on the importance of the sustainable use of resources).
- Review and update the ministerial decisions on wood exploitation (e.g. adapt the conditions and time frame for exploitation for different regions and forest types, and simplify the administrative procedures for wood exploitation and give priority to the local community.
- Capacity building (e.g. conducting ongoing trainings for loggers, and issue certificates for loggers who underwent trainings).

The ratification of Environment Law 444/2002, and the completion and endorsement of the National Land Use Master Plan (prepared in 2004 and enacted by the COM in 2009) are expected to have positive implications for Lebanon's environment including biodiversity and forests. Most recently, The Lebanese Parliament subsequently approved in March 2010 Law 92 banning all land uses inside burnt forests to prevent future acts of arson.

The Lebanese Government has set the strategic goal to achieve a 12% increase in renewable energy by 2020. A National Energy Efficiency and Renewable Energy Action was created in 2014, in the framework of the National Energy Efficiency Action Plan (2011), as a financing mechanism to support environmentally sustainable projects. The spectrum of available technologies envisaged is quite wide, including converting waste biomass into energy. In 2012, a National Bioenergy Strategy for Lebanon was prepared with the support of UNDP, as a fundamental contribution to the Government's goal of achieving a 12% increase in renewable energy. A total of twenty-three biomass streams representinga potential resource for energy production have been identified and fully characterized. Among the ten most promising bioenergy streams are the residues from forest thinning and pruning, among others (Encinas et al. 2015).

However, the National Forest Law and Lebanon's National strategy for forest fire management addressed various legal and strategic aspects in relation to managing municipal forests and forest fuel. Below is a review of relevant articles and items.

Forest Law issued (January 7, 1949)[2]

Article 1 – A forest means a land containing different trees, of big or small sizes, swirling on each other, or bush containing small trees not locked together, of kind that is generally used only for industry and fuel.

Article 11 – The RDNRD puts a system for forest investment ensuring its simultaneous exploitation, improvement, and continuous reforestation. The system is ratified by the Minister of Agriculture.

Article 54 - The forests that are owned entirely by villages are managed by municipalities to which they belong. Otherwise, they would be managed by village committees according to a special organizational arrangement placed by decree.

Divisions of any sort on the ownership of these forests are not allowed to be carried out among the population of the village.

Article 55 – Mayors or village committees appoint specialized forest guards at their own expenses to maintain their forests, and such appointments will be effective only after the authentication of RDNRD.

The RDNRD can terminate the appointments of those guards or it can isolate them.

Article 56 – The specialized forest guards are empowered with the same powers and functions of the public forest guards.

Article 57 – It is not possible to invest in the forests of the villages except in accordance with their regulations for investment. Each investment must obtain, in advance, permission from the RDNRD whether to cut trees, pick up fruits, or grazing among others.

Authorization must not be granted for cutting trees at ground level. An authorization will be granted by a decree only under compelling circumstances.

Also, it is not possible to transfer, store, and trade products from forests of municipalities and villages except in accordance with the provisions of Articles 33, 34, 35, 36 and 37.

Article 58 - The Municipal Council or the village Committee will be in charge of directly investing in the forest or through concessions after the approval of the RDNRD and in accordance with its prescribed conditions.

The provisions of Articles 19 and 20 are applied to mayors, and village committees.

Article 59 – The villages may not break the cadastral boundaries of their belonging forests without a special license through a decree based on an investigation carried out by the RDNRD.

Breaking a cadastral boundary is considered, by virtue, any illegal investment, extraction of trees, or permanent grazing of new spring spot in newly cut forests.

[2] *Unofficial translation from Arabic*

Article 60 – The RDNDR or its employees do not charge municipalities and villages compensation for carrying out prosecutions in relation to their forests and for any other work in relation to monitoring and management, and putting investment plans.

Article 61 - The third of the net income from the sale of products from the forests of villages and from leasing pastures in these forests are mandatory saves in reserve funds by the mayor or the head of the village committee who are personally responsible for the enforcement of this measure. This third is used under the control of the RDNRD for afforestation works that take place on the territory of the village itself and in accordance with the provisions of Article 88.

In the absence of communal lands subject to afforestation in the village, the communal body has the right to use this third in buying a barren land for afforestation.

Article 62 - The distribution of some forest products among the people of the village takes place according to custom and habit unless there is a contradicting instrument.

The municipal council or village committee is in charge of this task for distribution. The municipal council of the village committee will have to decide whether selling the products for the benefit of the town and the village rather than distributing them among the population of the village.

Article 63 - If the forest village was associated to rights of forest utilization independent of the right of investment for the town or village, these rights are identified and used in accordance with the provisions of Part II of the Law.

The provisions of Articles 38, 39, 40 and 41 which are competent with overviewing cutting sites are applied to the forests of municipalities and villages.

Article 93 – It is prohibited to cut trees of stone pine, Aleppo pine, Grecian juniper, cedars of Lebanon, Cilician fir and other resinous trees from privately owned forests and from communal and public forests except by technical thinning. A thinning license will not be given except for an individual holder of a certificate from the RDNRD signed by the Minister of Agriculture and proving his/her afforestation of an area equivalent to two thousand square meters for each fifty trees of the type that is desired to be cut.

Article 100 - If extraction of building materials and or cutting trees from forest lands are required by Public Works, then the Ministry of Public Works will indicate to the RDNRD the extraction and cutting areas before proceeding with the work.

The RDNRD in agreement with the Ministry of Public Works Terms will determine the conditions for extracting materials and cutting trees while conserving the forest. The RDNRD will determine when necessary the appropriate compensation to be paid to the State for working the land, and for the value of extracted material.

Article 101 – It is prohibited to set and transfer a fire outside the housing and buildings for investment within the forests boundaries as well as outside these forests within less than two hundred meters from the border in question.

This prohibition applies from July 1 to October 31, and it also applies to private forest owners and it includes the production of coal, tar and gum distillation, and in general all industries that require the use of fire, taking into account the provisions of Articles 102, 103, 104 and 105.

Article 106 - No one is allowed to burn thorns, grass, straw and other plants, unless having a

license from the RDNRD, on lands located less than five hundred meters from the forest and for the period extending from the July 1 to October 31, and on lands located less than two hundred meters from November 1 to June 30, unless otherwise permitted.

Article 110 – It is not possible to establish any industrial enterprise that uses fire or has to establish a repository of fuel inside the forest or on a land of less than two hundred meters from the border of the forest without acquiring a license from the RDNRD.

Decree No. 1576 on April 5, 1950[3]

Article 23 – Communal Forest investment works are organized with the purpose of promoting the growth of trees until it reaches the largest size possible and subject to the provisions of Article 57 of the Forest Law.

Article 26 – It is possible to sell out forest products or lease pasture communal land only through public auction or by sealed envelope after the approval of the Ministry of Agriculture, etc.

Law to preserve the forest and forest wealth No. 85 dated September 7, 1991

With the absence of adequate control starting 1975, Lebanon's forests have been exposed to various types of abuse and infringement, and that's what led to the enactment of Law No. 58 on the date of September 7, 1991.

Article I – It is forbidden to cut and manufacture all resin type of trees including stone pine, Aleppo pine, cedar of Lebanon, Cilician fir, Grecian juniper, cypress, and all other existing resinous trees within the forest owned by the State, the municipalities and villages, or individuals, etc. Public work projects conducted by the public institutions and licensed construction projects are exempted.

Working with Article 93 of the Forest Law is suspended.

Decision Number 4331/1 dated 30/8/2010[4]

The Minister of Agriculture signed a decision bearing the number 433/1 and dated 30/8/2010 in respect of "regulating forest and other wooded land harvesting". According to the text of the Decision, the following was decided among others:

Article One: allows maintenance or investment in forests according to the following:

(a) General conditions of pruning and thinning:

1. Pruning is allowed from September 15 to April 15 of each year, and requests for pruning should be received in the forest centers of MOA from July 1 to February 15 of each year.
2. The duration of daily work for investment works and transport is set from sunrise until sunset (work at night is forbidden).
3. It is strictly forbidden of introducing livestock grazing within the limits of sections invested for ten years.

[3] *Unofficial translation from Arabic*

[4] *Unofficial translation from Arabic*

4. Cutting a one-trunk tree is forbidden.
5. Pruning is allowed according to the following conditions: the removal of some twigs and branches:

   - Removal of curved branches and saving of three branches in every shrub given that the diameter of the branch is not less than 7 centimeters.

   - Branches of one-trunk trees are pruned up to a maximum of one third of the height of trees.
6. Shrubs are allowed to be thinned according to the following conditions:

   - If the slope gradient is between 40 and 50%: you should always hold on to at least sixty shrubs per dunum (i.e. 1000 m2) to be distributed uniformly over the entire property.

   - If the slope gradient is between 15% and 40%: you should always keep at least fifty shrubs per dunum to be distributed uniformly over the entire property.

   - If the slope gradient is less than 15%: you should always hold on to at least forty shrubs per dunum to be distributed uniformly over the entire property.
7. The forest ground should be cleaned from all twigs and branches resulting from the work process to prevent fires, and so on at least twenty meters from roads and buildings.
8. Fuelwood is transported according to specific permits issued by the competent forestry centers of MOA.
9. Fire sources and ignition are forbidden within the limits of forests and a distance of less than two hundred meters from the limits of forests and inhabited places.

Note: These conditions are considered an integral part of the license and every violation of the above-mentioned conditions makes its perpetrator subjected to prosecution jointly with the property owner.

Article three: (a) It is allowed to cut off or break trees that hinder the reclamation of abandoned farmlands in accordance with the following conditions:

1. The forest cover should be below the 30% of the total property area.
2. The slope gradient should be below 40%.
3. The trees subject of cutting should be broadleaf trees only.
4. The acquisition of the Green Plan's[5] approval (if the reclamation project is on the account of the Green Plan).
5. Provide a pledge at the notary to re-plant not later than 6 months from the date of issuance of the permit with determining a penalty clause in the pledge at a rate of 200,000 Lebanese pounds for every cut tree or shrub in addition to the right of the Minister of Agriculture to issue a decision requiring the caller to reforest the property in the three-year deadline. Otherwise, either the text of the application of Article 97 of the Forest Law in terms of acquisition of this land and auction it to be reforested is applied or the land is seized for reforestation at the expense of the Ministry and the caller shall be exempt from these two items in the case of force majeure, which is due appreciation to the Minister of Agriculture.

6. It is strictly forbidden to cut old and rare trees that are determined by MOA based on legal provisions in force.

Consulting with the Ministry of Justice[6]

The Ministry of Agriculture has raised many questions regarding the application of the forest laws and asked the Ministry of Justice to clarify the application of the Law in some cases. Accordingly, several legal counseling have been issued including:

Counseling No. 405/2006 dated July 19, 2006: according to which it is possible to grant a license for thinning dense stone pine forest as long as it leads to preserving the forest wealth and taking care of it.

Counseling No. 813/2004 dated December 6, 2004: It is not possible to cut down resinous trees in order to reclaim the property and plant it with fruit trees.

Counseling 498/1992 dated September 15, 1992: It is not possible to license cutting of resinous trees damaged by climatic factors.

Counselling No. 67/2000 dated February 1, 2000: It is allowed to log dead conifer trees killed due to insects and diseases and transport them outside the forest in order to avoid the spread of insects and diseases to healthy trees. This was based on the objective of Law 85 to preserve forest wealth. There is a need, however, to make sure through the technicians that affected trees are completely dry.

Based on these counselling it is clear that the Advisory Board's decisions at the Ministry of Justice are related, on one hand, to the identification of the objective of cutting for preservation of forest wealth, and on the other hand, to the technical opinion. In this context, the goal of a forest management plan that is developed by specialists is very often protecting the forest, and simultaneously ensuring its sustainability and maintenance. Accordingly, the development of a management plan is in line with the Law No. 85 (1991) and the forest law materials issued in 1949. Since the RDNRD is in charge of the protection of forest wealth, it is the only party that can bring, accompany, and monitor the implementation of a forest management plan.

Lebanon's National Strategy for Forest Fire Management (Decision No. 52/2009) [7]

Lebanon's National Strategy for Forest Fire Management (Decision No. 52/2009) addressed various aspects related to forest fuel management.

Item 3 of the Second Component of the Strategy (in Risk modification: fire vulnerability reduction and prevention of harmful fires) indicates:

- Develop and explore opportunities (i.e. innovative management systems, economic incentives, etc.) to help adopt fire resilient land uses and landscape pattern.

[5] The Green Plan is a public administration established in 1963. Its mandate is to execute agriculture infrastructure projects

[6] Unofficial translation from Arabic

[7] Unofficial translation from Arabic

- Modify risk through a number of means (i.e. traditional farming practices with some controlled and enforced livestock grazing in forests; encouragement of sustainable fuel wood collection; Incentives for farmers/herders not to burn crop residue and pastures during “fire danger” times; encouragement of Non-Wood Forest Products which can play a role at reducing risk; and incentives for farmers to have ploughed fuel breaks around the perimeter of fields).

Item 5 of the Second Component of the Strategy (in Risk Modification, Fire Vulnerability Reduction and Prevention of Harmful Fires) indicates:

- Develop preventive silviculture and fuel management aiming at reducing the highly flammable biomass and management of the forests to increase their resistance to fires (or reduce their susceptibility to fires); this includes but is not limited to grubbing and pruning, tree thinning, brushwood crushing, prescribed burning, controlled grazing and species selection.

Item 5 of the Fifth Component of the Strategy (In Recovery, Post-Fire Management and Rehabilitation) indicates:

- Develop post-fire active restoration/rehabilitation protocols and activities (forest landscape restoration).

- Facilitate natural forest regeneration and undertake reforestation activities in areas where regeneration is not possible.

Item 6 of the Fifth Component of the Strategy (In Recovery, Post-Fire Management and Rehabilitation) indicates:

- Support ecological restoration actions undertaken by the Department of Forests and Natural Resources at the MOA to recover resilient vegetation types for reducing fire risk and assist the natural regeneration by protecting the burned ones.

Item 7 of the Fifth Component of the Strategy (In Recovery, Post-Fire Management and Rehabilitation) indicates:

- Develop post-fire snags and woody debris management guidelines for the Lebanese forest ecosystems and forest areas, and modify the existing legislation that prohibits the removal of burned trees accordingly.

Forest resources assessment

Lebanon's country report of the global forest resources assessment (FRA) indicated that the forestry sector evolved towards reemitting the exploitation of fuel wood and charcoal in broadleaved forests after a decade of prohibition (FAO 2010). It was noted that this change which was partly demand driven, followed in parallel by the reinforcement of the number of forest guards in order to better control forest exploitation. This enabled MOA to increase the public revenues from the forestry sector, as well as the increase of job opportunities related to this field.

On the other hand, coniferous forests exploitation remains far-off due to law restrictions. Consequently, the absence of management resulted into the increase of disturbances in these forests. Insects and fungi outbreaks, winter storms damages and forest fires are more frequent, and more aggressive, thus reducing the biomass and carbon stock of coniferous species. The FRA report showed that in 2010, there was a slight increase in the forest area due to reforestation activities by municipalities in communal lands (Table 4).

Table 4. Forest areas from as reported by FRA 2010

	Area (1000 hectares)			
FRA 2010 categories	1990	2000	2005	2010
Forest	131	131	136.5	136.9
Other wooded land	117	117	106	106

Table 5. FRA 2010 distribution forest categories

	Forest area (1000 hectares)	
FRA 2010 Categories	2005	2010
Production	7.8	8
Protection of soil and water	34.2	34.4
Conservation of biodiversity	3.5	3.5
Multiple use	91	91
Total	136.5	136.9

Also, the FRA report provided data on growing stock (Table 6) which was defined as volume over bark of all living trees more than 10 cm in diameter at breast height (or above buttress if these are higher). It included the stem from ground level or stump height up to top of bole.

Table 6. Growing stock

	Volume (million cubic meters over bark)			
	Forest		Other wooded land	
FRA 2010 Categories	2005	2010	2005	2010
Total growing stock	4.863	5.097	0.533	0.548
… of which coniferous	3.466	3.639	0.382	0.394
… of which broadleaved	1.397	1.458	0.151	0.151
Growing stock of commercial species	1.397	1.458	0.151	0.154

The growing stock of the 10 most common species in forest was provided for the year 2005 (Table 7). The rank refers to the order of importance in terms of growing stock.

Table 7. Growing stock of top common species

FRA 2010 category / Species name			Growing stock in forest (million cubic meters)
Rank	Scientific name	Common name	2005
1st	Pinus pinea	Snawbar mothmer (stone pine)	1.518
2nd	Pinus brutia	Yarz (Brutia pine)	1.273
3rd	Pinus brutia	Turkish oak	0.940
4th	Cedrus libani	Arz (Cedar of Lebanon)	0.304
5th	Juniperus excelsa	Lezzab (Juniper)	0.284
6th	Quercus infectoria	Aafs (oak)	0.182
7th	Quercus calliprinos	Sendian (Live oak)	0.173
8th	Juniperus drupacea	Defran (Juniper)	0.088
9th	Platanus orientalis	Delb (Oriental plane)	0.019
10th	Ostrya carpinifolia	Shrekk (Hope horn bean)	0.016
Remaining			0.066
Total			4.863

Figures of biomass stock (i.e. Above Ground Biomass and Below Ground Biomass) were also provided by the FRA 2010 (Table 8). The growing stock data and wood density were used to obtain the stem biomass. However, there were no available or estimated data about dead wood weight in Lebanon. Dead wood was defined as all non-living woody biomass, not contained in the litter, either standing, lying on the ground or in the soil. It includes dead roots lying on the surface and stumps larger than 10 cm of diameter. Above Ground Biomass was defined as all living biomass above the soil including stem, stump, branches, bark, seeds and foliage. Below Ground Biomass was defined as all living biomass of live roots (root diameter above 2 mm).

Table 8. Above ground and Below Ground Biomass

	Biomass (million metric tonnes oven-dry weight)			
	Forest		Other wooded land	
FRA 2010 category	2005	2010	2005	2010
Above-ground biomass	2.780	2.913	0.304	0.313
Below-ground biomass	0.751	0.775	0.082	0.084
Total	3.531	3.688	0.386	0.397

Industrial wood removal is still prohibited in and not applicable to Lebanon. The only industrial activity is artisanal handicraft, which quantities are negligible and difficult to estimate and valuate. For estimation of woodfuel removals, charcoal and fuel wood were merged together (Table 9). The FRA 2010 report estimated that one ton of fuelwood costs 200 USD which is 300,000 LBP. Each cubic meter average price is estimated to 411,000 LPB. A ton of charcoal (requiring 4t of wood) is sold at 1,000 USD (1,500,000 LPB). Also, the report noticed an increasing trend of the total value due to a higher demand on fuelwood.

Table 9. Woodfuel removal

FRA 2010 Category	Wood removals 2005
Total volume (1,000 m^3 overbark)	18.2
… of which from forest	12.7
Unit value (local currency / m^3 overbark)	411,000
Total value (1,000 local currency)	7,780,200

As for employment in the forestry sector, the FRA 2010 estimated that five tons of fuel wood ready for use or charcoal production requires 6 Full-time equivalents (FTE) days. FTE is a measurement equal to one person working full-time during a specified reference period. One ton of charcoal requires 6 FTE-days. Thus, to produce 18,200 m^3 (9100t of wood/charcoal) there is a need of 10920 FTE-days or 49 FTE (on the basis of 225 working days per year). One ton of pine nut (white grain) harvesting requires 200 FTE-days. Pruning and cleaning the understory of one hectare of Pinus pinea (260 trees/ha) trees requires an average of 64 FTE-days every four years, or 16 FTE-days per year. Stone pine exploitation requires 390,560 FTE days or 1,736 FTE (for 1,500 t of pine nuts produced on an area of 5,660 hectares). The total of 401 496 FTE-days per year has been divided by 225 working days per year to estimate the number of man-years FTE. Self-employment is roughly estimated to one third of the total employment. Overall, the report noted an increasing trend of employment in primary production of woods with the higher demand on fuel wood and pine nuts, especially in deprived areas. However there was a decreasing trend of paid employment/self-employment since people are not keen to work in forestry activities that are usually less remunerating than other type of employment.

Bioenergy potential from the forest biomass

At present diesel oil is well established as a source of energy. However, the major economic, environmental, and social benefits of biomass are expected to gradually shift in favour of biomass and away from diesel oil when the briquettes begin to be better known through improved distribution and a competitive price (Encinas et al. 2015).

In reference to the National Bioenergy Strategy for Lebanon (UNDP/CEDRO 2012), forest wood biomass stream presents an interesting theoretical potential. However, this potential is considerably difficult to develop for several reasons: forests are located in the mountains where the first preoccupations are reforestation and biodiversity protection, and many exploitable forests are privately-owned, therefore, inducing some limitations and challenges. Also, "sustainable harvesting" is difficult to establish with the outdated laws and weak law enforcement.

Yet, Law 85 prohibits cutting in all conifer forests, which in majority, are state forests, easily exploitable for bioenergy production. Efforts are currently deployed by NGOs, in collaboration with the Ministry of Agriculture to reactivating management rights in public land. As such, harvesting forests is not allowed in Lebanon except for broadleave species such as Q. infectoria and Q. calliprinos for charcoal production. Also, law enforcement is weak; hence it is very difficult to assess the cutting permit volumes and geographic distribution for broad leave species. According to the UNDP/CEDRO (2012) 60% of wood cutting activities are not recorded. This percentage differs depending on the caza, geographical specificities and consequently on the type of trees.

Pruning of forests in Lebanon could be allowed (but is not yet developed) only through a forest management plan considering sustainable harvesting and providing a sustainable resource for bioenergy production. Accordingly, "sustainable harvesting plan" and legislative changes are required (UNDP/CEDRO 2012).

The bioenergy potential was estimated considering that forests can be harvested in a sustainable way (UNDP/CEDRO 2012). In this context, sustainability means linking harvest volumes with the forest regeneration cycle (UNDP/CEDRO 2012). As such, estimation was made only with pine forests and broadleaves forests, meaning with 82% of total forests, taking into account that that cedar and juniper forests are either protected or located in difficult harvesting areas.

The time needed for the regeneration of the broadleaved forests in Mount Lebanon, Beqaa, and other areas were estimated at 15, 25, and 20 years respectively. It was assumed that:

- Lower Heating Value of forest wood is between 14.0 (low assumption) and 18.0 (high assumption) MJ/Kg.
- Average moisture content for forest wood is 20%.
- Heating Value is defined as the amount of energy released when a fuel is burned completely in a steady-flow process and the products are returned to the state of the reactants. The heating value is dependent on the phase of water/steam in the combustion products. If H_2O is in liquid form, heating value is called HHV (higher Heating Value). When H_2O is in vapor form, heating value is called LHV (Lower Heating Value).

Accordingly, UNDP/CEDRO (2012) estimated that the total primary energy potential of woody biomass and fellings ranges between 1952 and 2510 TJ/year, which is a relatively significant amount. The methodology used to breakdown the living biomass per caza was to calculate a weight production potential by caza,

while taking into account the surface area of forests and the density of the forests. The density of dense forest was estimated at 65% and the density of sparse forest and shrubs was estimated at 10%. These figures were applied to each caza. This enabled the calculation of the energy potential from forest harvesting for Lebanon per caza (Table 10), using the formula:

Energy potential = Quantity of biomass available (below + above ground biomass) x 82% (excluding cedar and Juniper because they are either protected or located in difficult harvesting area) / (Years necessary to respect forest regeneration) x (1- moisture content) x heating value of forest wood.

Table 10. Energy potential estimate for living biomass per caza

	Weighted Biomass		Forest Regeneration (years)	Potential Estimate (GJ)	
	Above Ground	Below Ground		Low	High
Beirut	**68**	**20**	**20**	**41**	**52**
Baabda	148,113	44,434	15	117,839	151,507
El Metn	174,059	52,218	15	138,481	178,047
Chouf	235,054	70,516	15	187,009	240,440
Aaley	100,550	30,165	15	79,997	102,854
Keserwan	202,667	60,800	15	161,242	207,311
Jbeil	214,926	64,478	15	170,995	219,851
Mount Lebanon	**1,075,368**	**322,610**	**15**	**855,563**	**1,100,009**
Tripoli	596	179	20	356	458
Koura	45,031	13,509	20	26,870	34,547
Zgharta	101,504	30,451	20	60,568	77,873
Batroun	181,565	54,470	20	108,340	139,294
Akkar	307,522	92,257	20	183,499	235,927
Bcharre	91,648	27,494	20	54,686	70,311
Menieh Daniyeh	184,550	55,365	20	110,121	141,584

	Weighted Biomass		Forest Regeneration (years)	Potential Estimate (GJ)	
	Above Ground	Below Ground		Low	High
North Lebanon	912,417	273,725	20	544,439	699,993
Zahle	18,130	5,439	25	8,654	11,127
West Bekaa	38,320	11,496	25	18,292	23,519
Baalback	197,659	59,296	25	94,352	121,309
Rachaya	72,018	21,605	25	34,378	44,201
Hermel	107,575	32,272	25	51,352	66,024
Bekaa	433,695	130,108	25	207,029	266,180
Saida	16,801	5,040	20	10,025	12,890
Sour	99,477	29,843	20	59,358	76,317
Jezzine	207,981	62,394	20	124,102	159,560
South Lebanon	324,259	97,278	20	193,485	248,767
Nabatiyeh	53,382	16,015	20	31,853	40,954
Bent Jbeil	44,630	13,389	20	26,631	34,239
Marjeyoun	44,840	13,452	20	26,756	34,401
Hasbaya	111,341	33,402	20	66,437	85,420
Nabatiyeh	254,193	76,258	20	151,677	195,013
Lebanon	3,000,000	900,000		1,952,234	2,510,015

Also, sustainable forestry management through maintenance of the forest can provide a regular stream of biomass for energy. Pruning of trees, extraction of residues and shrubs, and fire risk management practices can generate biomass. The assessment of such a stream is based on assumptions of volumes produced and pruning frequencies. Considering that cedar and juniper forests are either protected or located in difficult harvesting areas, estimation is made only with pine forests and broadleaves forests,

meaning with 82% of forests that can be gathered. Moreover assuming a four-year frequency for pruning in Lebanese forests (although we consider that this is a very short rotation), and considering that residues represent 20% of the total tree volume, the energy potential for residues from fellings was estimated per caza as indicated in Table 11 (UNDP/CEDRO 2012). Accordingly, the wood residue stream from thinning operations and final felling are an interesting bioenergy potential that ranges from 1,378 to 1,771 TJ/year of primary energy.

It is noted that the overall potential evaluated cannot be achieved fully given that parts of the forest are located in areas where pruning or extraction of residues is challenging due to difficult access and steep slopes for conventional logging machinery. However extracting methods such as the cable logging method can be implemented as a remedy in areas where access is difficult. Cable logging is usually not considered for access reasons. We assume here that the crucial factor is forest protection. As it is more expensive than other methods, we only resort to it when the value of forest is high, and there are subsidies.

Table 11. Energy potential estimate for residues from felling per caza

	Weighted Above Ground Biomass	Potential Estimate (GJ)	
		Low	High
Beirut	**68**	**0**	**0**
Baabda	148,113	68,014	87,446
El Metn	174,059	79,928	102,764
Chouf	235,054	107,937	138,776
Aaley	100,550	46,172	59,365
Keserwan	202,667	93,065	119,655
Jbeil	214,926	98,694	126,892
Mount Lebanon	**1,075,368**	**493,809**	**634,897**
Tripoli	596	274	352
Koura	45,031	20,678	26,587
Zgharta	101,504	46,611	59,928
Batroun	181,565	83,375	107,196
Akkar	307,522	141,214	181,561
Bcharre	91,648	42,085	54,109
Menieh Daniyeh	184,550	84,745	108,958

	Weighted Above Ground Biomass	Potential Estimate (GJ)	
		Low	High
North Lebanon	912,417	418,982	538,691
Zahle	18,130	8,325	10,704
West Bekaa	38,320	17,596	22,624
Baalback	197,653	96,762	116,694
Rachaya	72,018	33,071	42,519
Hermel	107,575	49,398	63,512
Bekaa	433,695	199,153	256,054
Saida	16,801	7,715	9,919
Sour	99,477	45,680	58,731
Jezzine	207,981	95,505	122,792
South Lebanon	324,259	148,900	191,443
Nabatiyeh	53,382	24,513	31,517
Bent Jbeil	44,630	20,494	26,349
Marjeyoun	44,840	20,591	26,474
Hasbaya	111,341	51,128	65,736
Nabatiyeh	254,193	116,725	150,076
Lebanon	3,000,000	1,377,600	1,771,200

According to UNDP/CEDRO (2012) the combination of forest residues, short rotation coppices residues, and agricultural residues are very suitable for co-firing in power plants, for heat production in boilers, or for its combustion in Combined Heat and Power (CHP) plants. The bioenergy streams factsheets as produced by UNDP/CEDRO (2012) are provided in Table 12.

Table 12. Bioenergy stream factsheets

Bioenergy stream:	Woody biomass and felling	
DEFINITION: Trees, shrubs, bushes, or products derived from these woody plants		
Characteristics		Source
Calorific value	14.0 to 18.0 MJ/kg	FAO Forestry Department: Energy conservation in the mechanical forest industries (193)
Moisture content	Average 20%	Source: Agricultural Residues as Biomass Energy, H. Unal; K. Alibas, Department of Agricultural Machinery, Faculty of Agriculture, University of Uludağ, Turkey (July 2010)
Transformation and valorization technologies	Combustion: direct combustion, drying and pyrolisis	-
Transportation requirements and issues	Sustainable forestry management issue	-
Bioenergy stream:	**Residues from felling**	
DEFINITION: Forest residue chips or logs from final fellings (tops, branches, bark), thinning (whole tree chips), de-limbed small-sized trees (stem chips) or stumps		
Characteristics		Source
Volume ratios (waste or residues)	Top branches and foliage: 23% of tree; Stump (excluding roots) 10%; Saw dust 5%	FAO Forestry Department: Energy conservation in the mechanical forest industries (193)
Calorific value	14.0 to 18.0 MJ/kg (recoverable Heating value)	FAO Forestry Department: Energy conservation in the mechanical forest industries (193) Amane analysis
Moisture content	Average 20%	Source: Agricultural Residues as Biomass Energy, H. Unal; K. Alibas, Department of Agricultural Machinery, Faculty of Agriculture, University of Uludağ, Turkey (July 2010)
Transformation and valorization technologies	Drying and combustion	-
Transportation requirements and issues	Improvement of methods of harvesting to reduce wastes Collection at the same time as log extraction Loss of a valuable soil nutrient (have to be left in the forest: bark, leaves and thinning) Fire fighting	-
Economic barriers to realizing the potential	Collection and handling costs Transportation costs	-

Moisture content is averaged at 20% (Table 12), but we doubt this is this too low for Lebanese conditions at least, given that felling or pruning is not done in summer.

A SWOT analysis was conducted to most relevant biomass resources of the bioenergy strategy (UNDP/ CEDRO 2012) among which residues from forestry felling. The main results of the SWOT analysis are represented in Table 13.

Table 13. SWOT analysis on residues form forest felling

Internal factors		External factors
Strengths (S):	**Weaknesses (W):**	**Opportunities (O) and threats (T):**
High calorific value (from 14 to 18 MJ/kg)	Main technical disadvantage on its extraction in inaccessible areas of the country.	No current habits of practicing pruning in forests. Initiatives have to be suggested in order to stimulate the availability of residues belonging to pruning and felling activities.
Low moisture content (average 20%)	Collection, handling and transportation costs could be considered high investment needs.	The extraction activities of residues from felling should be done as per controlled techniques. Otherwise, its removal would contribute to impoverish the chemical characteristics of the operated soil, as some valuable soil nutrients have to be left in the forest.
Removal of residues from the ground contributes to decreased fire risk	-	-
Null amount of water needed to grow it	-	-

CHAPTER 3

FOREST BIOMASS STRATEGIC OBJECTIVES

Strategic objectives

The main identified strategic objectives that will help realize the full potential of Lebanon's forest biomass included:

1. Support Research and Development (R&D) investment that will provide foundation for the future management of Lebanon's forest biomass
2. Promote necessary policy tools, reforms in legislation, and law enforcement
3. Identify and support opportunities for the development of forest biomass

Support Research and Development (R&D)

Currently, there is only one educational institution in Lebanon, namely the Lebanese University that provides a degree in forestry (i.e. Master degree in forest engineering). Forestry related issues are given only as secondary courses or credit in universities that have BS and MS degrees in agriculture and environment related subjects. This could be attributed to the minor economic importance of forestry in Lebanon.

In the last decade, Lebanese universities have seen a gradual increase in environmental diploma courses and degrees, and the number of environmental students is rising slowly but surely. Student data from leading universities show that the American University of Beirut, University of Balamand, Saint-Joseph University, Lebanese University, Saint-Esprit de Kaslik University, Notre Dame University, Lebanese American University, and the Arab University are graduating dozens of students from environment-related majors (sciences, engineering, health, etc.). Most of these universities have established environmental centers with full-time staff. At least 16 centers and institutes were counted (MOE/UNDP/ECODIT 2011). Over the long-term however, the continued appeal of environmental majors in Lebanese universities will depend on the job market. To assess the job market situation, the International Labor Organization (ILO) and UNDP commissioned a nationwide study to assess green job potentials. Results showed that renewable energy, waste, and agriculture (Integrated Pest Management and organic agriculture) have the potential to offer the greatest number and diversity of green jobs (MOE/UNDP/ECODIT 2011).

Lebanon has a dynamic research community that brings together both public and private institutions. This research community, however, is constrained by limited funding and oftentimes works in disconnection from the environmental research needs of the surrounding society. There is no easy way to bridge research initiatives with the environmental issues and problems facing Lebanon but several examples attest to great advances in research and development that have led to tangible environmental results (MOE/UNDP/ECODIT 2011).

In general, Research, Development, and Outreach in forest biomass could represent a thriving area of research and development in the private sector as well as in universities and governmental agencies. It would be essential to be assured through an ongoing commitment to research that forest biomass use will not conflict with conservation and stewardship goals.

Equally, a commitment to outreach is also needed, in order to get the most up-to-date science into the hands of decision-makers, forest managers, landowners, and community groups among others. The following recommendations address policies for research, development, and outreach as it relates to bioenergy from sustainable forest biomass management:

- Explore the effectiveness of woody biomass as a means of achieving silvicultural objectives and conservation goals.
- Establish a competitive grant program for sustainable forest biomass research to better understand the implications of harvesting greater quantities of woody biomass on the sustainability of our forest resources, with a focus on ecosystem function, soils, water, and biodiversity.
- Create and institutionalize many more green jobs in the coming decade to sustain the flow of fresh graduates.
- Provide needed technical and financial support to all aspects of technology research, development, demonstration, deployment, marketing, financing, operation, and maintenance.
- Conduct joint research efforts (i.e. national and internationally) between research institutions and industries, aimed at renewable energy applications and collaborative efforts to carry out renewable energy resource assessments.
- Combine efforts with industrialized countries to promote knowledge transfer and the development of appropriate bioenergy technologies for Lebanon.
- Conduct research on current/potential biomass supply and value chains.

A greater understanding of these matters would not only help forest managers develop better management directives, but it will also help policy makers to refine and adapt national forest biomass and bioenergy policy in the future.

Agencies that may support R&D in the forest biomass sector include a large number of private universities (e.g. American University of Beirut, University of Balamand, Notre Dame University, Universite Saint-Esprit Kaslik, Lebanese American University, and the Beirut Arab University among others) in addition to the Lebanese University, National Council for Scientific Research (NCSR), and the Lebanese Agriculture Research Institute (LARI), among others.

Promote necessary policy tools, reforms in legislation, and law enforcement

Key activities that can help in promoting necessary policy tools, reforms in legislation, and law enforcement are mainly organized into four pillars: capacity building, policy support, technology transfer, and market development.

Capacity building

For forest biomass markets to develop and deepen in Lebanon, capacity building is required in all areas of project and program design, development, implementation, and operation. This entails a long-term commitment, with activities focusing on individuals, institutions, and systems, and aimed at public, private, and non-government organizations. Suggested capacity-building activities include the following among others:

- Integrate forest biomass management for bioenergy into national development strategies in agriculture, forest conservation and sustainable use, poverty alleviation, and energy.
- Train policymakers on policies and programs for accelerating adoption of bioenergy from forest biomass by municipalities or union of municipalities.
- Train law enforcement individuals and teams (e.g. forest guards of MOA and Internal Security Forces, among others) on improved legal monitoring of forest activities and works and accordingly, taking necessary legal measures against violators.
- Strengthen municipalities and relevant enterprises to source, integrate, install, operate, maintain, and service bioenergy systems; provide business training and incubation support.
- Provide training and technical assistance on standards for bioenergy development, drawing on international efforts in this area (e.g. the European Union, the Global Bioenergy Partnership, and the Roundtable on Sustainable Biofuels, among others).
- Provide training workshops to governmental agencies (e.g. Ministries of Environment and Agriculture) and the private sector on the Clean Development Mechanism (CDM) and official and voluntary carbon markets.
- Conduct communications and outreach on bioenergy benefits/challenges, including consumer awareness campaigns.

Policy support

It is essential that biomass harvesting be incorporated into existing political framework, practices, and culture of sustainable forestry (i.e. NFP). This will help realizing the benefits of expanded markets without risk of overharvesting forests.

Sustainable forestry must be built from the ground up, through policies that enable thorough risk assessments, make available science-based management guidelines, and incorporate biomass harvesting considerations into programs and policies that promote site-level environmental decision-making in forest management. In this context, issues such as harvest levels, diameter limits, and other specific management practices, should not be prescribed at the national level, because of the regional variability in ecology and geography (e.g. the forest of Bkessine has different biophysical characteristics of from the forest of Andket in North Lebanon).

The following policy recommendations, among others, will help to install biomass harvesting as one element in a holistic sustainable forestry paradigm, in order to minimize negative environmental impacts and maximize the utility of biomass markets as a tool for achieving stewardship goals:

- Establish a high-quality rigorous system of national environmental indicators that tracks trends in forest condition (i.e. water quality, air quality, soil resources, biodiversity) in order to understand how biomass harvesting is impacting overall environmental quality.
- Encourage the creation of communal forest biomass general harvesting guidelines to give guidance and understanding regarding suggested management practices unique to biomass removal.
- Establish a collaborative, multi-stakeholder body to explore how biomass harvesting can serve as an ecological restoration tool on public lands. In this context, collaborative environments can be very effective at building trust, sharing value systems, and fostering creative management solutions. A collaborative body may contain representatives from the land management agencies, universities, environmental organizations, and other stakeholder and community groups to explore the role of biomass harvesting on public lands.
- Establish a technical assistance program at MOA for biomass supply assessments. Resource assessments and management plans will help provide for sustainability at the national level and on individual forest holdings. Otherwise, local demand could drive overharvesting, supply shortages, and price spikes, resulting in bioenergy applications that are ecologically and economically unsustainable.

In addition, the rural development policy should highlight the use of forest biomass as a source of renewable energy that is produced in rural areas. It is to be noted that rural dwellers in Lebanon make up 13% of the total population (CAS 2009). Many of the rural communities are located in mountainous regions where the winters are cold and wet. That is why the consumption of fossil fuels for heating purposes in these areas is much higher than in the milder parts of the country.

Technology transfer and technical development

As previously stated, forest residues and short rotation coppices residues are very suitable for co-firing in power plants, for heat production in boilers, or for combustion in combined heat and power plants (UNDP/CEDRO 2012).

In the rural areas of Lebanon the stoves used for heating homes are of the traditional type. They are composed of a simple combustion chamber directly connected to the chimney and only have an outside air intake. Some stoves have been modernized with oil tanks as fuel to generate heat and are located inside the house, where one breathes the strong smell of diesel fuel. The stoves configuration, whether they burn wood or diesel fuel, does not allow the proper dissipation of heat, and most of them are underperforming at rates of up to 55%. The main advantage of the existing stoves is the low purchase price (Encinas et al. 2015). Economic stoves with higher yields could be designed in a simple way.

Bioenergy categories suitable for woody biomass include the following (BRD 2011, Wild 2011, Yung et al. 2009, Mitchell et al. 2008):

Heat Energy – Through the exothermic combustion process, wood or woody biomass, is converted into the primary products of carbon dioxide, water, inorganic ash, and various gaseous and particulate emissions while giving off about 2.344 KWh of heat for every 0.45 kg of dry wood burned.

Electrical Energy – Coupling the combustion process with a steam boiler and using the produced steam to drive an electrical turbine is a well proven method of producing electricity from woody biomass.

Biofuels – Many types of woody biomass derived biofuels are possible but only the following fuels have proved to be economically viable:

- Solid or milled wood – wood in any size or shape can be directly combusted to produce heat and as such is a biofuel…firewood and wood chips are common market categories.
- Densified wood – wood particles are compressed into a smaller volume of a specific size and shape (pellets, logs, bricks, etc.) to increase the fuel density, ease of transportation, enhance storage durability, or improve other burning characteristics.
- Charcoal – Produced by subjecting wood to a slow pyrolysis process in the absence of oxygen for many hours) that thermally degrades the wood into an aqueous liquid fraction (tar), a gaseous fraction, and a solid fraction consisting mostly of carbon (char) that is formed into charcoal.

Until present, Lebanon does not present any projects or initiative to stimulate the use of biomass in the country. The country has not counted on any organized initiatives of collection and removal of residues from pruning and felling. It has not been found that any other projects have been developed in previous years with those specific purposes. Most recently, two local initiatives have been started by UNDP-CEDRO to launch one plant for briquette production in partnership with the Municipality of Bkessine and another one in partnership with the Municipality of Andket. Such initiatives were preceded by developing a forest inventory, a management plan, and harvest plan for each of the two forests.

Due to the fact that the forests in Lebanon are widespread (i.e. fragmented landscape and poor accessibility to forest biomass), collection, handling and transportation activities are significant inconveniences. Because of all these purposes, the logistic costs will be raised and could suppose a substantial reason for making this feedstock unviable. Some road infrastructure is necessary in order to facilitate transportation to reach different forestry zones and enhance communication among them. Therefore, forests need to be accessible, and providing forestry zones with adequate and well-maintained roads will improve accessibility structures. However, the subject of opening new roads in forested areas is still controversial in Lebanon given that many risks and threats (e.g. fires, land degradation, landscape fragmentation, etc.) to the forest cover could be associated to these types of roads (Figure 8).

Figure 8. Road opening coupled with forest cover degradation (source: Mitri, G.)

Also, residues from felling are not just hard to have access to at some locations but their removal entails a loss of soil nutrients. Certain contents of nitrogen, phosphorus, potassium, calcium and magnesium constitute part of the chemical properties that define a specific sort of soil. When needles, twigs and branches are collected from soils with bioenergy purposes, chemical properties are modified and soil is impoverished due to major loss of nutrients. To avoid soil productivity losses, it is necessary to determine the optimal balance between the residues removal and the benefits of biomass and Greenhouse gas offset. Reaching the balance among these aspects requires several experiments that would be expensive and not always possible to develop. To deal with these impacts, scientists have developed analytical frameworks and simulation approaches for defining the optimal collection procedures. Accordingly, some control over collection techniques of forestry residues is required in order to avoid potential soil degradation due to nutrients removal. Analytical frameworks, simulation approaches or any software usages are fully recommended in order to monitor the quality of remaining soil when possible.

Using the BAT (Best Technology Available) for processing the biomass (e.g. drying) on a large scale according to specific needs is another issue of importance. Efficient equipment would reduce the energy needs of the pre-treatment plant. Some financial supporting aids are recommended in order to equip plants with the best technology available.

Importation of equipment and spare parts is needed, however, it is important to stimulate the Lebanese technological industry to avoid a dependence on equipment importation in the long term, encouraging the development of its own equipment industry and market on bioenergy technology.

Finally, a number of technologies involving biomass projects and program opportunities have potential for use in Lebanon and should be explored in more detail. However, this will require assessment of technical, institutional, financial, environmental, social, and economic considerations, as well as a review of related experience in other countries.

Finance and market development

On one side, finance and investment are key elements to the growth and development of the forest biomass sector in Lebanon. Public and private sector resources will be needed to meet the financing requirements of managing the forest biomass sector for bioenergy. Activities to be conducted include among others:

- Engage local financial institutions and micro-credit agencies in biomass and relevant bioenergy projects.
- Foster development of "bankable" project portfolios in biomass and relevant bioenergy initiatives; offer assistance to entrepreneurs in areas such as R&D, seed capital funding, pre-feasibility and feasibility assistance, reimbursable grants, etc.
- Conduct donor coordination roundtables to brief prospective donors on biomass and bioenergy activities and secure their participation.
- Explore opportunities for carbon finance at the national levels.
- Exempt import tax on bioenergy equipment to support the different forest biomass energy options.

On the other side, improved markets for woody biomass have potential to reduce costs associated with hazardous fuels reduction, wildlife habitat management, ecosystem restoration, and other proactive stewardship activities. Biomass and bioenergy programs can be designed to advance economic and social development, and increase jobs and raise income. Much can be learned from success and failures from experiences gained in other EU-Mediterranean countries. In this context, traditional and modern stoves and low-tech processing systems are key elements to sustain the market for woody biomass products from forests. Meanwhile, CHP, or cogeneration, plants are relatively large-scale operations, and they require a significant and reliable source of forest residues and sustainable woody biomass.

Identify and support opportunities for the development of forest biomass

This strategic objective will require pooling needed resources (i.e. financial mechanisms), and knowledge and expertise (i.e. building collaboration and supporting the establishment of public-private partnerships through the involvement of national and local stakeholders).

Financial mechanisms

Ratification of major environmental conventions and treaties by the Lebanese Government has secured sizable grants and program funding from the international community. Leading development organizations include the Global Environment Fund (GEF operates through implementing agencies such as UNDP, UNEP and the World Bank), the Agence Francaise de Developpement (AFD), the Canadian International Development Agency (CIDA), the European Union (EU), the French Global Environment Facility (FFEM), the German International Cooperation (GiZ), the US Agency for International Development (USAID), and many others.

Kyoto Protocol Adaptation Fund was created in 2009 and it is financed by a share of proceeds from CDM project activities with the aim of financing concrete adaptation projects in developing countries that are Parties to the Kyoto Protocol. The main goal of the fund is the financing of determinate projects in developing country Parties to the Kyoto Protocol who are vulnerable to climate change.

Nationally, the "Reforestation Fund" (so-called Sandouk al Tahrij) stipulated by the Forest Law of 1949 (Article 98) is the principal source of funding. However, the law needs reactivation and improved management through the responsible Commission (Article 89) consisting of the Minister of Agriculture as president, and the Ministry's Director General and the Chairman of the Forestry Department as members. Once reactivated, the "Reforestation Fund" can help in funding the implementation of the previously discussed instruments. It is needless to say that the reactivation of this fund might help in getting better access to international funds in the form of grants and loans, among others.

Also, the Forest Law of 1949 mentioned that municipalities and villages are required to keep the third of the net revenues from forestry products and forest investments as reserved funds for later afforestation/reforestation activities within the municipalities' lands. This resource can be used in the implementation of community forests as part of the mitigation actions. MOE drafted a decree to setup the National Environmental Fund pursuant to Law 444/2002 (Articles 8, 9, 10 and 11). According to this decree, the fund would have a legal identity, financial and administrative autonomy, and would fall under the mandate of the Ministry of Environment. Funding and fund replenishment would come from several sources including provisions in the Government's annual budget, environmental fees, grants, fines and compensations, and interest on deposits.

The banking and private sectors are very important partners that can financially help in conducting biomass and bioenergy projects. Also, the National Energy Efficiency and Renewable Energy Action (NEEREA) loans present good incentives for developing forest biomass projects. NEEREA is a national financing mechanism initiated by the Central Bank of Lebanon (CBL) in collaboration with the Ministry of Energy and Water (MEW), the Ministry of Finance (MOF), UNDP, the European Union (EU), and the Lebanese Center for Energy Conservation (LCEC). NEEREA allows private sector entities (individuals, SME's, or corporate bodies) to apply for subsidized loans for any type of Energy Efficiency and/or Renewable Energy projects. NEEREA covers loans by any Lebanese commercial bank with 0.6% interest rate and a repayment period of up to 14 years, in addition to a grant amount released after the project is implemented. The architecture of NEEREA is as follows:

- MEW sets the strategic guidance and priority in energy efficiency and renewable energy.
- As national financing institution, CBL sets the framework of operation and offers benefits to banks.
- MOF defines the subsidies on interest rates for the different sectors of the economy.
- EU has offered BDL a grant of 12 Million Euros to encourage SME's in applying for NEEREA.
- UNDP partnered with CBL to offer technical support, training, marketing, and awareness raising activities.
- LCEC is the technical consultant to CBL, reviewing loan applications, and setting quality control criteria.

Stakeholders

The MOA would have lead responsibility for Blueprint coordination. This effort will include a consultation process conducted at the national level, engaging policymakers, forest scientist and managers, the private sector, and civil society. Also a number of external organizations including the international financial community, private companies, university and research centers, bilateral/multilateral organizations, would be engaged in relevant consultation processes. The technical and financial support of these organizations will be essential to the success of biomass and bioenergy projects and initiatives. Also, as part of the Blueprint management effort, a Forest Biomass Advisory Task Force would be formulated. The Task Force will be comprised of experts representing key stakeholder groups (Table 14) across the country, to advice on sustainable bioenergy development from Lebanon's forest biomass sector.

Table 14. List of stakeholders and their roles in the forest biomass sector in Lebanon

Stakeholders	Roles and responsibilities
Ministry of Agriculture	• Undertake forest management activities • Revise and work on updating relevant laws and regulations • Provide necessary permits for silvicultural treatments such as pruning and thinning • Develop trade off mechanisms (i.e. compensations and incentives) to get community buy-in and empowering local communities to adopt proper biomass management activities • Provide effective monitoring and control of silvicultural treatments • Provide technical support to the Municipality for the implementation of its plans for regeneration, plantation, and silvicultural treatments • Ensure the proper implementation and enforcement of forest laws and regulations • Provide flexible framework for the adoption of fire resilient forest cover • Monitor the arrival and outbreak of certain pest and diseases that can affect trees
Ministry of Environment	• Ensure nature conservation • Provide necessary information about the environment • Develop in consultation with the MOA a participatory spatial planning process to agree on landscapes with more resilient types of land uses and spatial distribution of uses
Ministry of Interior and Municipalities	• Mobilize means of fire suppression and train individuals from the local community on forest firefighting (through the General Directorate of Civil Defense) • Ensure law enforcement through the Internal Security Forces and provide support to the forest guards of MOA • Mobilize municipalities to manage their forest communal lands (through the Directorate of Municipalities)
Ministry of Energy and Water	• Contribute to relevant bioenergy issues • Support activities relevant to forest-water issues

Stakeholders	Roles and responsibilities
Ministry of Finance	• Undertake necessary financial and tax issues (e.g. tax exemption on bioenergy equipment) • Provide support on identifying forest land ownerships
Ministry of Justice	• Apply suitable and relevant sentences • Improve legislation • Provide an updated and flexible legal framework for the adoption of forest management and harvest plans
Ministry of Economy and Trade	• Control and manage the market development • Conduct quality control
Municipalities and unions of municipalities	• Contribute to forest fire risk management through the involvement of neighboring municipalities • Mobilize necessary resources for forest fire prevention and risk management • Contribute to raising awareness campaigns for the local community groups about the benefits of sustainable forest management practices • Monitor the arrival and outbreak of certain pest and diseases that can affect trees • Manage the implementation of forest management plans • Manage the implementation of forest harvest plans • Ensure sufficient financial resources for the implementation of the forest management and harvesting plans • Launch the tenders for pruning and thinning (if needed) • Acquire all necessary permits and licenses for pruning and thinning activities in the forest • Provide and operate necessary infrastructure/equipment for processing biomass residues • Ensure adequacy and maintenance of forest infrastructures and installations • Build the capacity of users about good practices on silvicultural treatment and fire management (in case they are allowed) based on the existing regulations. • Develop agreements with companies/administration/privates responsible of forest infrastructures on the necessary investments and periodic works for their maintenance • Monitor the proper use of recreational facilities • Develop awareness campaigns about the fundamental role that the rural population plays in protecting the forest preventing dangerous fires • Raise awareness to general public by posters and signposts which warn the public about the danger of forest fires which are placed at conspicuous places of roads, picnic and camping sites and villages
Pruning and thinning contractors	• Familiarize themselves with the harvesting plan • Ensure they are trained to properly implement activities suggested in the harvesting plan • Undertake proper pruning and thinning techniques • Ensure proper handling and disposal of pruning and thinning products

Stakeholders	Roles and responsibilities
Cooperatives in the forest business	• Propagate seedlings in local nursery and originating from local seeds • Provide high quality seedlings (free from diseases and damages) for reforestation • Provide seedlings certificate of origin • Monitor the arrival and outbreak of certain pest and diseases that can affect trees
National Research Centers (e.g. NCSR and LARI)	• Undertake biomass/bioenergy research activities including monitoring forest health • Develop exchanges with "nodes of expertise" on forest biomass and bioenergy issues • Bridge innovative biomass and bioenergy knowledge with traditional management practices • Support the use and application of appropriate technologies in bioenergy from forest biomass
Universities	• Set-up specific forest curricula in universities/research institutions where forest experts should be prepared and undertake needed research works • Undertake biomass/bioenergy research activities and studies • Develop forest inventories, management plans, and harvesting plans • Investigate relevant environmental issues and give relevant suggestions to forest managers • Develop effective monitoring systems (indicators to be measured, methodologies, databases) and set up systems for the collection of relevant data (qualitative and quantitative)
Local community groups and NGOs	• Promote responsible forest-related activities (e.g. ecotourism) • Provide support to municipalities in biomass management • Secure funds for the implementation of forest management and harvesting plans • Engage in annual training activities in biomass management • Involve aware individuals from the community to whom awareness raising and surveillance campaigns are addressed, in the awareness, education, and surveillance actions
Banking and private sectors	• Financially help in conducting biomass and bioenergy projects (e.g. loans, grants, etc.) • Undertake necessary investments to encourage implementation forest biomass management plans • Develop funding mechanisms for the implementation of silviculture treatment works
International Organizations	• Provide international expertise • Provide technical and financial support

CHAPTER 4

MANAGEMENT AND IMPLEMENTATION

Discussing the legal and technical framework

The Decision 433/1 and dated 30/8/2010 comes in line to a certain extent with the Forest Law and it is expected that the required permits for harvesting and thinning can help in preventing abuses in the forestry sector. However, it was observed that the Decision allowed pruning between September 15 and April 15 of each year, while tree burgeoning and flowering can start as early as mid of March, especially in areas below 500 meters above sea level (Figure 9). Accordingly, pruning should not exceed March 15 of each year especially under a changing climate scenario. Yet new laws are needed to be formulated on the principle of sustainable forest management and conservation of ecosystems and biodiversity in forests and woodlands.

Figure 9. A wild almond tree flowering early February in 2014 (source: Mitri, G.)

Also Decision 433/1 deals with only broadleaf trees while resinous trees such as confiners are not mentioned. Working resinous trees such as Pinus brutia should be regulated and organized because they are considered as useful investments for locals. Besides, large and dense Pinus brutia forest represent a favorable environment for fires and the failure to regulate their investment will not help in preventing relatively large scale fires (Figure 10). Accordingly, Pinus brutia forests should be allowed to be pruned and thinned based on scientific forest management and harvesting plans to reduce fire hazard in these forests to promote economic income to local communities.

Figure 10. Dense P. brutia forest (left) in Andket North Lebanon (source: Mitri, G.) and intense fire (right) in the Andket forest (source: AFDC)

A web-based decision framework to improve fire risk management was recently developed (Mitri et al, 2014b). The primary objective of the application (FireLab) was to provide an online user-friendly interface for displaying data that are critical for making informed fire-management decisions (Figure 11). Data include 257 variables related to fire activity, risk, and hazard and are generated at the municipality level for all of Lebanon. FireLab is delivered through a web browser, making it widely accessible to the public in a format that allows users to easily display wildfire conditions and to describe and share modeled wildfire potential scenarios of current and future conditions. As such, it is recommended to use such tool at different levels (i.e. local and National) to extract needed information related to forest vegetation cover and its associated fire hazard and risk.

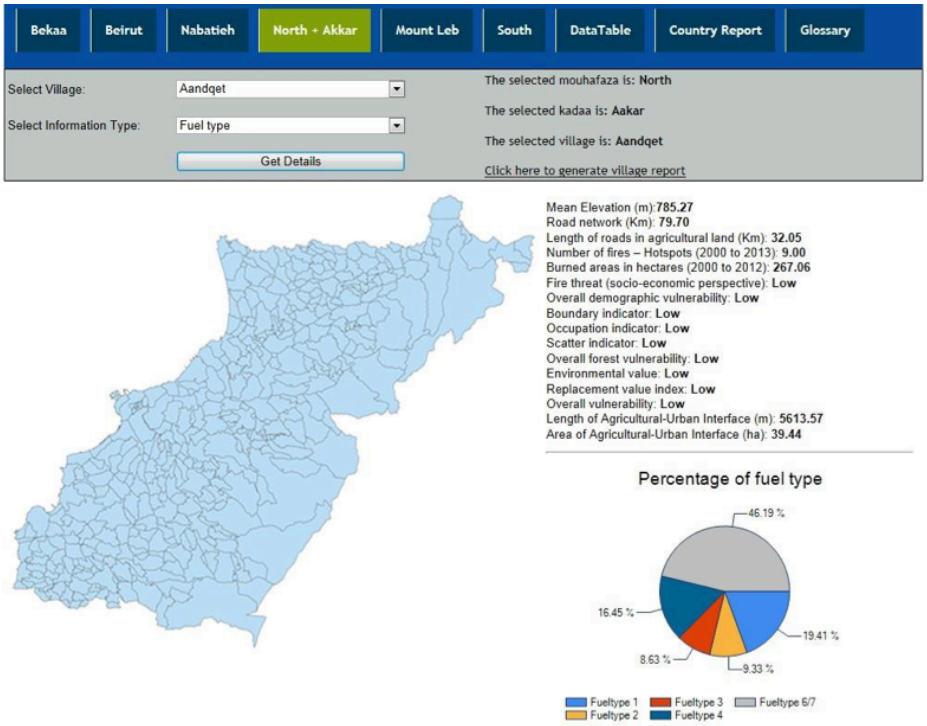


Figure 11. Screen shot of the main interface of the FireLab web-application tool (source: Mitri et al, 2014b)

Also, within the framework of the project "Firewise-Lebanon" developed by the Institute of the Environment at the University of Balamand in Lebanon and Lebanon Reforestation Initiative (LRI - a project funded by the United States Agency for International Development and implemented by the United States Forest Service), best practice guidelines for:

- Managing fire risk in Lebanon's abandoned agricultural lands
- Managing fire risk in Lebanon's dense forests
- Engaging communities in developing plans for wildfire risk management activities were produced and published in both Arabic and English (IOE-UOB/LRI 2014). Accordingly, it is recommended that community groups villages and municipalities owning communal forest lands refer to such guidelines for future activities in relation to fire risk management.

The fate of forests that are owned by the State is still unknown and no plans are being undertaken to manage and protect these forests. Accordingly, proper forest inventories, management plans and harvesting plans should be developed for these forests to ensure their sustainability.

Yet, the development and finalization of a National forest policy or programme is needed to ensure the sustainability of forests and investment and to have forests able to perform their ecological role in light of climate change in addition to take advantage of them in light of the increasing demand for forest wood and non-wood products.

Pruning permits that are currently given in accordance with the existing regulations are not properly monitored. Although violators might be highly fined, but eventually, paid fines are very low and do not constitute a deterrent.

Most importantly, forest guards of MOA are not capable to deal alone with suppressing irregularities and simultaneously conducting all tasks related to overseeing, controlling and monitoring of works and investments in forests given their limited numbers and lack of needed equipment and technical/financial resources. It is to be noted that following up on such tasks is also the responsibility of other ministries. As such, illegal cutting of trees (i.e. in remote oak forest) remains a threat to the existing vegetation cover with the lack of efficient monitoring and control mechanism (Figure 12).

Figure 12. Clear cutting of oak trees (left) in remote forest areas in North Lebanon (source: Mitri, G.), and fuelwood gathering (right)

The process of Forest Management Planning

Forest inventory for sustainable forest management

Up until now, the information about Lebanese forest resources on the local, regional and national levels are still general or sometimes not existing, whereas the sustainable management of forested areas requires a more precise information system and a constant monitoring of the quantity and quality (forest stands, species composition) of forest resources. Specific forest resources information on wood volumes and growth is needed at the forest management unit level in order to determine sustainable yields of wood production. In this context, a forest inventory is considered as initial stage necessary to cover the data gaps and to develop national forest management plans (Table 15).

Table 15. Forest Inventory Terminology

Terminology	Description
Forest	Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (FAO 2010).
Other wooded land (OWL)	Land not classified as "Forest", spanning more than 0.5 hectares; with trees higher than 5 meters and a canopy cover of 5-10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent. It does not include land that is predominantly under agricultural or urban land use (FAO 2010).
Forest stand	A community of trees possessing sufficient uniformity in composition, age, arrangement or condition to be distinguishable from the forest or other growth on adjoining areas, thus forming a temporary silvicultural or management entity (IUFRO 2000). Even-aged stand: Stand or forest type, in which no or relatively small age differences exist among individual trees within it, usually less than 20% of rotation length (IUFRO 2000). Uneven-aged stand: Consisting of trees of a range of age classes, with age differences which are significant in relation to the stand structure management and rotation length (IUFRO 2000).
Forest Management unit (MU)	A permanent, geographically recognizable unit of forest land forming the basis for planning, prescription, implementation, monitoring and recording of forest operations. To the extent that it is practicable, areas of forest that are to be managed for different purposes, or have clearly different functions or values, should be placed in separately defined MU (FAO 1998). The basic permanent unit is obtained by joining the stands, and establishing clear natural or artificial limits that can be easily found in the maps or on-site during management works such as streams and roads.

Terminology	Description
Site index	Site index is a measure of a forest's potential productivity. Site index is usually defined as the height of the dominant or co-dominant trees at a specified age in a stand. It is calculated in an equation that uses the tree's height and age. Site index equations differ by tree species and region (USDA 2002).
Stand structure	The distribution of trees in a stand, which can be described by vertical and/or horizontal spatial patterns, size of trees or tree parts, age, or a combination of these (IUFRO 2000).
Basal Area (BA)	BA of a tree: the area (in square meters) of the cross section of the stem, usually at -> breast height; BA of a forest, stand or forest type: the area (in square meters per hectare) of the total cross section of all the trees at -> breast height (IUFRO 2000).
Diameter class	Any of the intervals into which the range of stem diameters of trees or logs is divided for classification and use. Also the trees or logs falling into such an interval (IUFRO 2000).
Volume increment	The increase in volume of individual trees or stands during a specified period (IUFRO 2000).
Standing volume	The quantity of timber measured in volumetric terms, standing or felled, over or under bark. Usually only including merchantable dimensions. It is calculated using diameter at breast height, height and form factor which is estimated from basal area and mean height (IUFRO 2000).
Biomass	Biomass is defined as the total amount of aboveground living organic matter in trees expressed as oven-dry tons per unit area (FAO 1997).
Biomass fractions	Stem biomass: biomass in the main tree stem Coarse biomass: biomass in branches > 2cm Fine biomass: biomass in branches < 2cm plus twigs and needles
Yield prediction model	A yield prediction model uses the quantitative relationships between measured growth variables to predict yields of forest types, and is a tool that helps to schedule and regulate harvests at sustainable levels (FAO 1998).

Forest Inventory Objectives

The main elements of a forest inventory depend very much upon the specific objectives of management. Three specific guidelines should be considered when determining inventory objectives (FAO 1998):

- Objectives need to be determined jointly by the people who will use the results, including forest managers, planners and decision-makers, as well as by inventory specialists. Inventory objectives should not be determined by inventory specialists alone.

- Not all inventory objectives have the same level of importance. Some have higher priority than others, and it is the objectives having highest priority that should determine the inventory design and the presentation of results.
- Inventory objectives should consider the physical effort that will be required to conduct an inventory, the organization, estimated costs and time, the existing knowledge of resources, the availability of specific aspects of inventory technologies and institutional capability. All have a direct bearing upon the implementation of an inventory. An overriding consideration is that an inventory must be practicable and achievable.

In forest management plans where biomass production is the primary objective, a wood resources inventory is always required to determine wood volumes, species, log qualities and utilization prospects for forest resources planning and for advertising reliable minimum estimates of volume for bioenergy production. For sustainable planning, additional secondary objectives would take into account social, environmental and economic aspects of the forest thus evaluating existing forest uses, forest composition and distribution, and non-wood resources.

In this document, the basic steps for the development of forest inventories, mainly for forest biomass production, are described. Accordingly, the main objectives of the forest inventories are:

1. To provide new qualitative and quantitative information on the state, use, management and trends of wood forest resources (FAO 2004)
2. To predict yields of forest types which help to schedule and regulate harvests at sustainable levels (FAO 1998).

Forest inventory process

The general steps for the development of a forest inventory are shown in Figure 13. The process mainly consists in field and desk work for data collection and analysis.

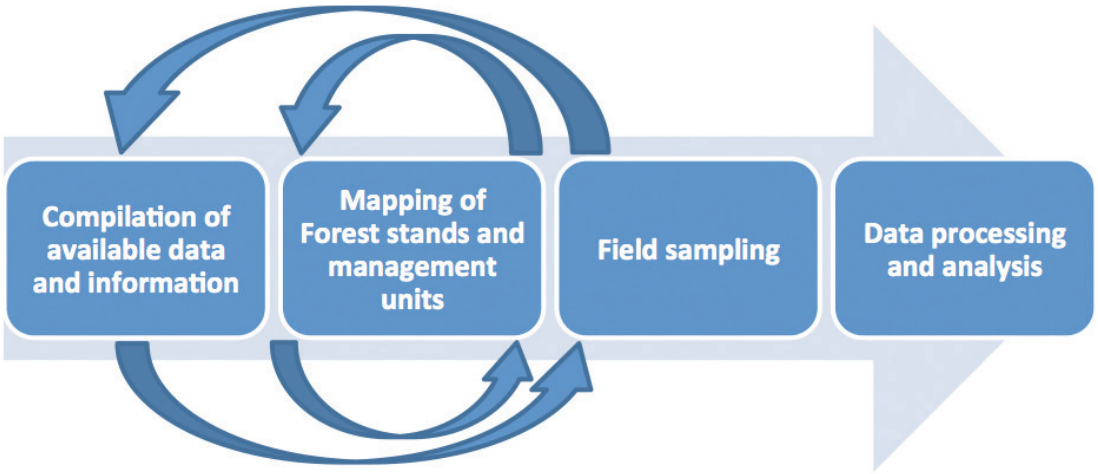


Figure 13. Steps for the development of a general forest inventory

The steps outlined in Figure 13 are described in sequence below.

a) Data compilation procedures

In forest inventories auxiliary information is necessary to prepare the field survey. Initially, a review of available information from scientific studies, national reports, should be conducted. Any previous inventories should be taken into consideration and future work should build-on, complement and improve the existing inventory data.

Moreover, relevant stakeholders such as local authorities (i.e. municipalities) and MOA forest centers in charge of the study areas should be contacted in order to assess data needs and current situation for inventory development. Since the implementation of communal forest management plans in Lebanon falls under the municipality's (or municipality union) responsibilities, the municipality staff where the forests are located should help in locating the lands and determining the ownership status of the land, knowing that management plans are usually developed for communal lands rather than private lands. Municipality staff may also provide information about access conditions to the site and about the people who can be locally recruited as guides or workers during the inventory field work.

b) Forest stand mapping: parameters for stand delimitation & data needs

RATIONALE (stand-based management): The aim of the forest stand delimitation is the definition of the minimum inventory and management unit areas presenting homogeneous site index and later silvicultural characteristics related to specific goals and objectives. The scale in forest stand delimitation maps usually ranges around 1:5,000 or 1:10,000, depending on species commercial value, stand characterization data, spatial data availability, and budget constraints. Stand delimitation is usually done in three iterative phases:

1. A preliminary stand delimitation draft is digitized, based on available geospatial information (e.g. topography, land-use/ land-cover maps, and satellite imagery)
2. It is used to evaluate the need for different strata, design the sampling scheme, and conduct the field sampling
3. The assessment of forest inventory data from sample plots measured in the field provides evidence to approve or modify cartographic lines and a final map is produced and used as the basis for planning.

Additionally, the final map should be also reviewed and approved by the local forest managers responsible of the treatments and future forest monitoring, as the delimitation is designed to be as permanent as possible over time.

As Mediterranean forests are multifunctional and support multiple uses, stand delimitation and sampling cannot focus only on accurate timber volume (growing stock) or biomass estimation from a certain number of sample plots. Other goals should also be taken into account when planning (i.e. livestock extensive grazing, honey, nuts/seeds, water harvest). Moreover, reduction of losses from abiotic (i.e. wildfires, wind throw, drought spells) and biotic agents (i.e. pests, diseases) also affect management. Therefore stand delimitation must accommodate current constraints in

use (i.e. private lands, protected areas) or hazards that may influence inventory. For instance, permanent pastoral or recreational areas designated by owners/management need to be identified as they will require different sampling schemes. Only if all the required information has been correctly structured (by the delimitation) and collected (by sampling), it is then possible to evaluate any spatial and temporal incompatibilities in goals, (analyzed through a forest use compatibility matrix), to optimize management.

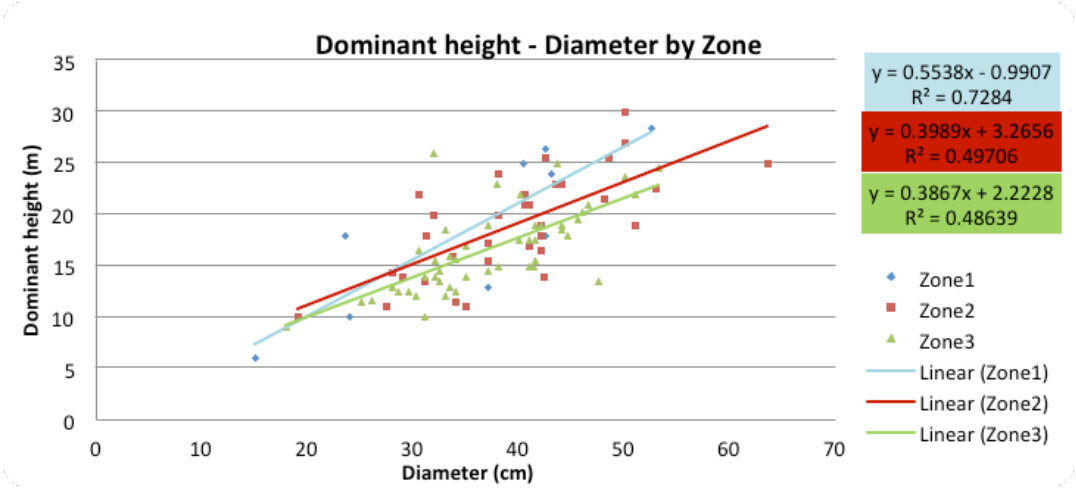
CRITERIA (parameters for stand delimitation and associated data needs): The main parameters and corresponding data (Table 16) to be used for stand delimitation are related to topography-site quality that will determine growth/living conditions, recognizable land features to identify stands in the field, previous management delimitations that may have influenced the land cover, or provide data on previous inventories or harvests, and current vegetation cover.

Site index (SI)

This is the stands´ biomass growth potential, it is species-specific and usually measured in classes or ranges that refer to average net annual growth (m^3/ha.year) or stand height (dominant height) at a certain age (e.g. Quality A = A m of dominant height at B years).

Field-measured heights or Light Detection and Ranging (LiDAR) data combined with stands age information are needed to accurately map the site index (SI). When this information is not available, it is possible to infer site quality by classifying areas presenting different aspect (i.e. north facing slope vs. south facing slope areas) and slope (indirectly related with soil depth, and, hence, to SI). Topographic differences are relevant in terms of radiation and available water in the Mediterranean basin, where there is at least one discernible deficit period during the year (summer). In places with an important altitudinal gradient, changes in elevation can also be an important factor to be considered. Also, current tree cover may provide insight on site quality. Once the inventory data are processed, dominant height and age can be extrapolated from sample plots to stands allowing estimation of SI or at least a site quality relative classification.

Box 1. Site index modeling in Bkessine Pinus pinea forest showed three functions for dominant height as a function of age for three different forest zones. Data indicate that dominant height at 50 years of age is around 25 m in Bkessine.



SI should be properly characterized in the areas were the harvesting will be carried out, after developing the accurate forest inventories for the biomass estimations. Determining the SI is a very important stand characteristic to plan the rotation temporal frame.

Land features, physiographic limits and infrastructures (LP)

Stands need to be easily recognizable in the field, and limits should be stable over time to allow for future forest monitoring. For that reason, river channels, topographic break lines (e.g. mountain tops and divides) and roads are usually good permanent border lines to be considered. Although the differences in the vegetation can be also taken into account for that purpose, they should be avoided unless the differences result from land uses in which management is not expected to cause substantial changes that could alter the current cover (e.g. sharp transitions in the vegetation from mature forest to pastures). Cartographic sources of roads, rivers and contour lines at medium-fine scales are usually set as reference. Any previous delimitation of management zones should also be taken into account for consistency with the local management practices. Lacking this information, fine resolution satellite imagery or aerial photography may be used. Contour line maps can be easily generated from the Digital Elevation Models (DEM) using GIS tools.

Tree cover (TC)

It is the proportion of the surface covered by tree crown projections, usually expressed as a percentage of the total surface (%). It is related with tree density, previous management, soil depth and natural disturbances. It is usually estimated visually with satellite imagery or aerial photographs using GIS tools. For that purpose at least 1:10,000 scale is needed.

Species composition (SC)

The dominant species and accompanying or non-target species in the overstorey are also accounted for, since the silvicultural treatments (i.e. thinning prescriptions and selected stand regeneration method) need to be in agreement with species requirements. Using satellite imagery (1:5,000-1:10,000 scale) it is possible to discriminate among some major species groups in the dominant tree stratum (e.g. conifer vs. broadleaf).

Stand structure (ST)

As previously described, a forest stand is a community of trees possessing sufficient uniformity in composition, age, arrangement or condition to be distinguishable from the forest or other growth on adjoining areas, thus forming a temporary silvicultural or management entity (IUFRO 2000). ST can also refer to the tree distribution per diametric classes which is known as even-aged and uneven-aged. Even-aged stand refers to a stand or forest type, in which no or relatively small age differences exist among individual trees within it, usually less than 20% of rotation length (IUFRO 2000).

Uneven-aged stand consists of trees of a range of age classes, with age differences which are significant in relation to the stand structure management and rotation length (IUFRO 2000). This parameter can be directly related with previous management and/or the occurrence of disturbances causing tree mortality. For delimitation purposes it can be evaluated visually from aerial photography or satellite imagery. Once the inventory data are processed, tree cover, species composition, crown stratification and diametric distribution will be accurately estimated by the field survey.

Minimum stand area

It is the minimum inventory and management reference surface considered in the stand delineation digitization process, usually 10 ha. This is a management-set lower limit based on forest goals, previously available spatial data, and human resources for management. However, if forest cover within stands is heterogeneous, smaller units down to 5 ha may be digitized for improved yield estimation, but these will not be considered to be permanent units and will homogenize with the application of the silvicultural prescriptions.

Stands of special interest (SS)

This parameter takes into consideration the areas presenting some singular physical-biological or socioeconomic features (e.g. the presence of endangered species, riparian vegetation or recreational areas) that forces to consider them independent management units. In these cases the area may be smaller than the established minimum stand area.

Table 16. Summary table containing the main parameters and sources of the parameters considered in stand delimitation.

Parameter	Data	Data source
Parameter	Aspect Slope Elevation Inventory data (heights, diametric classes, etc...) Geology Soil types	DEM Field assessment GIS layers
Land features, physiographic limits and infrastructures (LP)	Rivers Watersheds Contour lines Road network Forest boundaries Administrative boundaries Ownership maps Existing management zones	Satellite imagery Aerial photographs GIS layers DEM

Parameter	Data	Data source
Tree cover (TC)	Inventory data (tree density, crown shape, etc...) Burned areas	Field assessment Satellite imagery Aerial photographs
Species composition (SC)	Dominant species Inventory data Land use/land cover	Field assessment Satellite imagery Aerial photographs GIS layers
Stand structure (ST)	Inventory data (tree distribution in diametric classes, etc...) Burned areas	Field assessment Satellite imagery Aerial photographs
Stands of special interest (SS)	Recreation areas Protected areas Endangered species habitats Riparian vegetation Burned areas	Interviews Field assessment Satellite imagery Aerial photographs GIS layers

All the previous criteria and available information considered would be the basis for determination and description of the main forest typologies in the inventory areas. After the mapping process, detailed maps are produced to determine the field sampling plots design for use during the inventory data collection in the field.

c) Field sampling

Sampling design: The sampling intensity used in forest inventory is determined according to the forest structure, extent, and accessibility. In homogeneous conditions the sampling intensity could be estimated from random error formulas with a subsample of a few plots. In difficult accessibility conditions (extreme slope, lack of roads and very high density of understorey), the sampling could be done following a directed manner by only taking representative samples from the different identified forest typologies.

Field protocol and measurement sheets: Field survey protocols and measurement sheets (Figure 14) for data collection should be prepared and used in the field. The data collection is done using visual assessment and specific equipment for measurement of tree components. The main information which need to be measured and included in the data collection sheets are the plots layout and dimensions (circular, quadrats, radius, etc.), the usual dendrometric data (i.e. species composition, density, diameters-DBH, height/dominant height, age and radial growths (cores), tree configuration, bark thickness, canopy cover, regeneration, health status, spatial distribution, sociological structure, dead and dying trees, etc.), specific blocks for environmental values: ecological and biodiversity information, i.e. understory vegetation, dead wood, erosion, wildlife, unusual species, or aesthetic value.

Code plot	Code photos			Coordinate system	X	Y

Radius plot (m)					
Distance 3° tree	Distance 6° tree	Density N/ha	Radius (m)	Selected	Observations:
3	4	>1000	10		
4.5	6.5	400-1000	15		
9.5	13.5	100-400	30		
13.5	18.5	50-100	45		

Erosion evidences					
0	1	2	3	4	5
No erosion	Roots exposed and stones uncovered	Gullies present	Ditch and ravine on V	Ditch and ravine on U	Soil movements
Slope (%)					

OVERSTOREY TREE LAYER								
Specific composition:	Pinus pinea	Pinus brutia	Quercus calliprinos	Quercus coccifera	Quercus infectoria	Quercus pseudocerris		
Presence								
% cover								
Forest structure	Even-aged	Uneven-aged	Two-storied	Other				
If even-aged	Seedlings	Thicket stage	Pole stage	Timber stage				
Damages/losses (Biotic: fungi, insects, parasite wild animals, anthropic/Abiotic: fire, weather,								
Damaged elements	Bark	Leaves	Branches	Wood	Fruits	Flowers	Crown	Tree
L, M, H								

Regeneration status and distribution								
Species	Pinus pinea	Pinus brutia	Quercus calliprino	Quercus coccifera	Quercus infectoria	Q. pseudocerris		
Density								
Height (m)								
Spatial Distrib.(R, C, U)								

UNDERSTOREY SHRUB/GRASS LAYER					
Shrub Species					Herbaceous layer (cover, composition, palatability)
% cover					
Av. Height (m)					
Spatial Distrib.(R, C, U)					

Tree	DBH (cm)	Specie	Tree	DBH (cm)	Specie	Tree	DBH (cm)	Specie
1			17			33		
2			18			34		
3			19			35		
4			20			36		
5			21			37		
6			22			38		
7			23			39		
8			24			40		
9			25			41		
10			26			42		
11			27			43		
12			28			44		
13			29			45		
14			30			46		
15			31			47		
16			32			48		

SELECTED TREES INVENTORY			
Tree	1	2	3
DBH 1 (cm)			
DBH 2 (cm)			
Height first branch (m)			
Total height (m)			
Bark depth (cm)			
Crown shape			
Compressed	Tangent	Compressed	Tangent
Free	Umbrella	Free	Umbrella
Globular	Open	Globular	Open
Strata classes			
Dominant	Co-dominant	Dominant	Co-dominant
Emergent	Intermediate	Emergent	Intermediate
Supressed	Dead	Supressed	Dead
Dead & grounded		Dead & grounded	
Wood quality			
1 (perfect)	2	1 (perfect)	2
3	4	3	4
5	6 (dead)	5	6 (dead)

Crown shape		Strata classes		Wood quality	
Compressed	Tangent	Dominant	Co-dominant	1 (perfect)	2
Free	Umbrella	Emergent	Intermediate	3	4
Globular	Open	Supressed	Dead	5	6 (dead)
		Dead & grounded			

Figure 14. Example of a field data collection sheet per sampling plot

Field equipment: The implementation of the field protocol requires the specific equipment for sampling, measuring and recording and for the subsequent the calculation of growth parameters (Figure 15). The equipment needed to carry out the inventory is composed of:

- GPS receiver (Geographic Positioning System) and extra batteries (includes a Compass 360°);
- 2 self-rolling measuring tapes 10-30 m (metric);

- 2 diameter tapes (PI units) or caliper (metric);
- Tree height and land slope measuring equipment: hypsometers;
- Bark thickness gauges;
- Cores extraction from tree stem for tree age and growth estimation: Core drillers (increment borers);
- Colored marking chalk;
- Waterproof bags to protect measurement instruments and forms;
- Digital camera;
- Waterproof boots and outfits;
- Emergency kit;
- Topographic maps;
- Supporting board to take notes;
- Data collection forms;
- Field protocol;
- Permanent markers and pens;
- Flora and species list (common and scientific names);

Figure 15. Equipment for dendrometric data collection

(A- Blume-Leiss hypsometer, B- Vertex hypsometer, C- Bark thickness gauge, D- Increment borer, E- Caliper, F- PI tape)

d) Data processing and analysis

Data collected from field surveys are processed and analyzed to determine forest characteristics and to calculate growth parameters necessary for development of yield prediction models. Knowledge of forest growth provides a confident basis for the measurement of increment which can be used to derive wood yields for a production forest. Growth data are also required for planning operational aspects of management, for technical and for economic studies (FAO 1998). Analyzed parameters are listed in Table 17 along with the needed data for their calculation.

Table 17. Parameters generated from the collected inventory data

Parameter (Unit)	Processed inventory data
Site index (correlation, equation)	Height (m); diameter at breast height-DBH (cm); age; erosion evidences in forest health and protection
Stand structure (description)	Crown shape (compressed, tangent, free, umbrella, globular, open); strata classes (dominant, co-dominant, emergent, intermediate, suppressed, dead, dead and grounded); tree cover (%); present species; forest typologies (shrubland, low pole stage forest, high pole stage, etc.); and regeneration
Forest health (description)	Wood quality (scale 1-6, perfect to dead); pests and diseases; natural and human-made damages (fires, snow, pruning, etc...)
Age (years)	Tree stem cores (analyzed in the lab); DBH (cm)
Basal area (m^2/ha)	DBH, bark depth
Density (trees/ha)	Number of trees per sampling plots
Diameter growth (cm/year)	Tree cores radius of the last 10 years
Volume increment (m^3/ha)	Diameter growth, height
Standing volume (over bark) (m3/ha)	DBH; height; mean height; basal area
Green biomass (T/ha)	DBH; volume; Moisture Content (MC)
Dry biomass (T/ha)	DBH; volume; MC

Several published studies in the Mediterranean region have developed species-specific growth and yield models (i.e. de-Miguel et al. 2014, Manso et al. 2014, Pique-Nicolau et al. 2011, Shater et al. 2011, de-Miguel et al. 2010, Madrigal et al. 2009, Calama et al. 2008, SME 2008, Calama et al. 2005, Montero et al 2005, García Güemes et al. 2001, Martínez et al. 1993, Gezer 1985). The equations are used for volume and biomass estimation; however, it is strongly recommended that felled or fallen trees occasionally removed from the forest have their volume and biomass estimated to gather information for the future on which equation is more accurate or developing specific equations from simple regression analyses. Calculated volume estimates per plots are used to develop a summary of forest characteristics by management unit.

Box 2. Collected data in Bkessine forest allowed calculating plot-wise models for height in non-measured trees from DBH, used for volume estimation, and diameter increment (periodic annual increment, PAI, last 10 years) for yield estimations. The following equations were used for volume estimations (SME, 2008).

Pinus pinea: $V = 39.96+0.00033*(Dm^2)*(H)$

Pinus brutia: $V = 67.25+0.0002*(Dm^2)*(H)$ (P. halepensis)

Where, V is volume over bark (dm^3/ha) - Dm is the midpoint of the corresponding diametric class (10 cm for the range 7.5-12.5 cm; 70 cm for the 67.5-72.5 cm range) - H is the average height of the corresponding diametric class.

Biomass was estimated from simple regression equations as follows

Pinus pinea:

Coarse Biomass (>2 cm) $B_C = -6.455+Dm*1.986 /(1.4 \text{ or } 1.6)$

Fine Biomass (<2 cm) $B_C = -63.895+Dm*8.68 /(1.9 \text{ or } 2.1)$

In Andket, the timber volume within stands for the different diametric classes was estimated using the following individual tree equation (Martínez et al. 1993):

Where, $V_{w.b.}$ is the timber volume (dm^3) with bark on stand for a single tree with a d diameter at breast height with bark (cm) and h total tree height (m). Then, the timber volume in stands was estimated from the tree density and the single tree volume at the different diametric classes.

Also individual tree dry biomass for two different fractions, coarse biomass for firewood (i.e. tree trunk and thick branches Ø > 2 cm) and fine biomass for the briquette (i.e. thin branches Ø ≤ 2 cm) was estimated from Montero et al. (2005) and de-Miguel et al. (2014).

$B_C = (0.0816d^{2,133}) + (0.0784d^2 + (-1,9175d) + 14.207)$

$B_F = 0.0649d^{2.0349}$

Where, B_C is the dry coarse biomass (kg/tree), BF is the dry thin biomass (kg/tree), for a single tree with a d diameter at breast height.

Forest Management Plan

A forest management plan is an indispensable part of a forest management system and should regulate protection, inventory, growth & yield determination, silviculture, harvesting, and other forest operations, being foremost the planning and monitoring of forest regeneration and stand development over time.

Also, a forest management plan is required to provide continuity in managerial operations over time, to formalize administrative arrangements and to provide a basis for monitoring forest activities. A forest management plan has the purpose not only of setting out approved management objectives and specified action but, equally important, communicating these to people who are concerned with the implementation of a plan in a forest or group of forests to which it applies (Table 18).

It should be noted that effective forest management relies on the use of up-to-date and accurate information on forest types, wood volumes and growth, range of other environmental matters, local community and wider social relationships, and economic issues (FAO 1998).

Table 18. Forest management planning terminology (in reference to FAO 1998)

Terminology	Description
Forest Management Plan	The forest management plan is an indispensable part of a forest management system and should regulate protection, inventory, growth & yield determination, silviculture, harvesting, and other forest operations, being foremost the planning and monitoring of forest regeneration and stand development over time.
Goal	A goal is a long-term aim, derived from forest policies or determined as the end-point of a strategy to achieve sustainable forest resources development.
Objective	Objectives are measurable activities, or outputs, which state specific results to be achieved during a specified period of time.
Prescription	Objectives are measurable activities, or outputs, which state specific results to be achieved during a specified period of time.
Working Plan	A document that regulates wood production, silviculture and tending activities for a specific period of time through the application of prescriptions specifying targets, action and control arrangements. A Working Plan is not synonymous with a Forest Management Plan.

Goals and objectives of forest management

The identification of a management goal and specific objectives for a forest management unit, according to policy priorities, resources potential and constraints, is a basic forest management principle. Several goals and objectives may be determined and defined in a forest management plan (e.g. wood harvesting for bioenergy production, fire risk prevention, conservation of biodiversity

and enhancement of aesthetic value for recreation, etc.). Objectives should be specific, measurable, achievable, relevant, and time limited. They can be classified into primary objectives with high priority for implementation during the plan period and secondary objectives with lower priority but nonetheless achievable during the plan period. Accordingly, each objective should be clear about:

- What activities will be undertaken
- Where they will happen
- Who has responsibility for taking action
- When the action should be taken
- When action should be completed
- How much will be achieved, or specific quantitative statements concerning outputs
- Why an activity will contribute to achievement of an objective.

Objectives should be set in order to ensure sustainable forest management and the forest would be strengthened to fulfill short to long term economic, ecological and social functions.

Box 3. The 10-year Forest Management Plan of Andket which was developed in 2015 included one goal, namely to ensure an improved forest structure and productivity. The objectives were set to avoid the loss and the anticipated irreversible degradation of additional areas of the forest, ensure the improvement of its health, and supply fuelwood for local communities and biomass for bioenergy production.

Category	Objectives	Description	Priority
Production of wood	*Objective 1:* Biomass production for bioenergy	To implement silvicultural treatments for the production of biomass coming from residues harvested after pruning and thinning in the purpose of briquettes production	Primary
Conservation and protection	*Objective 2:* Forest fire prevention	To develop effective measures intending to reduce fire vulnerability, to increase ecological and social resilience to fire, and to prevent the occurrence of harmful fires and unsustainable fire regimes.	Primary
	Objective 3: Protection of natural resources	To ensure the conservation and improvement of biodiversity, maintain the productivity of soil, and minimize the impact of forest practices on water quality	Primary
Environmental Services and Social Promotion	*Objective 4. Community engagement*	To encourage the effective participation of the local community in the development of the forest management plan	Secondary
	Objective 5. Maintenance and enhancement of recreation	To provide the public with recreation facilities, services, and information	Secondary

Duration of Forest Management Plans

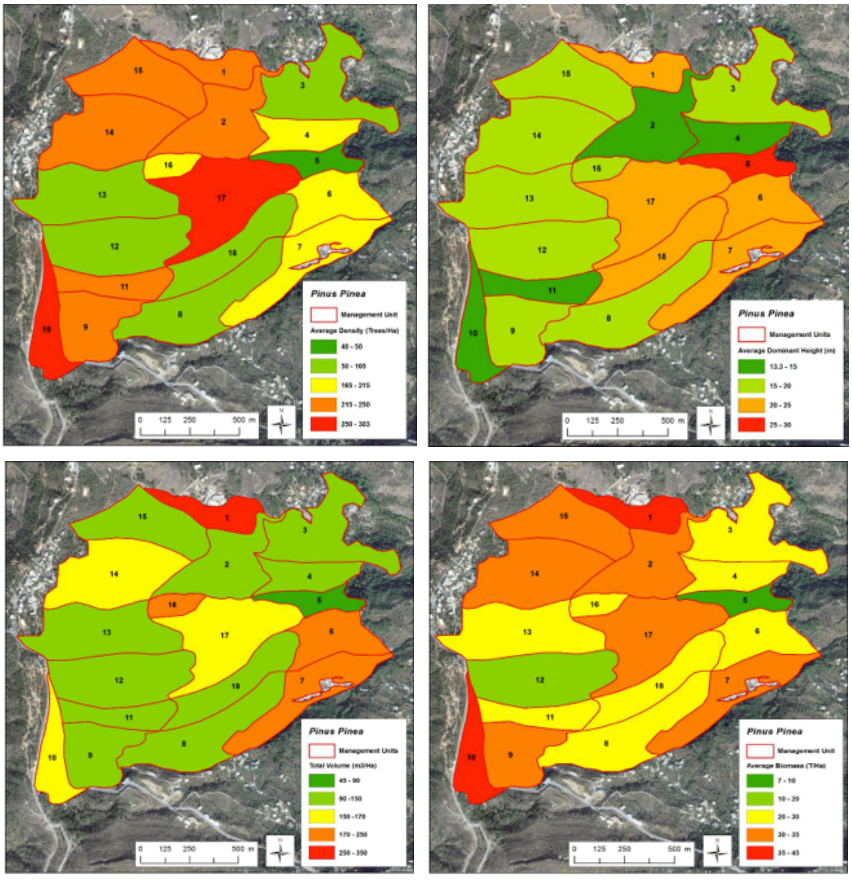
A forest management plans should have a minimum duration, or length, of 10 years. A shorter period than 10 years does not provide the medium-term stability that is needed to guide consistent implementation of sustainable forest management activities. The duration is also called the term, or period of a plan. A management plan should include a review procedure which provides for:

- Review at the mid-point of the plan,
- Review in the final year of the plan,
- The preparation of a new plan upon expiry of the present plan.

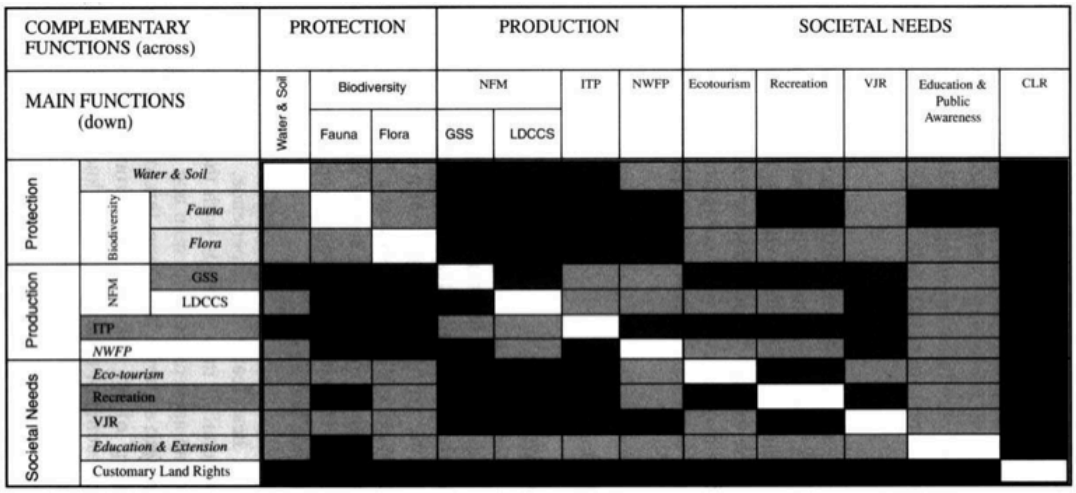
Management Units

The management units (MU) identified during the forest inventory procedure are used in the management plan to assign the tasks or the prescriptions to be implemented depending on the characteristics of each MU described in the inventory data processing and analysis (e.g. density, average height, volume, and biomass quantities, etc.).

Box 4. The forest inventory of Bkessine forest (developed in 2015) resulted in precise stand delimitation and identification of 18 management units (MU). The MUs are characterized according to density, dominant height, volume and biomass as shown in the maps below.



Each unit of the MUs is assigned to one or several objectives according to their characteristics in addition to other criteria such as proximity to roads, and ecotourism potential among others. In some cases, the conflict between objectives in the same area can be evaluated (FAO 1998) using compatibility matrix of forest functions (Figure 16). In the purpose of achievement of the objectives, several prescriptions could be suggested per MU and each prescription is related to a set of monitoring measures (indicators) and a priority for implementation (primary, secondary).



Compatible	Not Compatible	To Be Defined In Each Case	On All Slope Gradients	<%50 Slope	<%30 Slope
			Fauna	*LDCCS*	*Recreation*

Figure 16. Compatibility matrix of forest functions (source: FAO 1998)

CLR = Customary land Rights, IPT = Industrial Tree Plantation, GSS = Reduced Impact ground skidding, LDCCS = Long Distance Cable Crane System, NFM = Natural Forest Management, NWFP = Non-wood Forest Products, VJR = Spiritual and Religious uses.

Working Plan

Prescriptions should be organized following the short, the medium and the long term for the ten year period of the plan and they should be divided into primary and secondary as done for the objectives. A timetable for the prescriptions should be set covering the plan period and providing an easy-to-identify table of the tasks or activities that could be scheduled in a Gantt chart for the period of implementation.

The plan of activities should necessarily include the relevant stakeholders and needed human resources along with their roles in the implementation of the management objectives. Moreover, any required financial resources need to be separately analyzed for each task in order to identify the alternative sources of funding or to evaluate the feasibility of actions.

Legal constraints and obligations

In general, the forest management plan objectives and activities should be set in line with the existing legislation regulating the forestry sector and take into consideration all the related laws and decisions. However, in some cases recommendations derived from the recent analyses are not conforming to the legal constraints. This will require further efforts to provide practical recommendations. In both cases, all necessary permits should be acquired for any future work in the forest. Accordingly, detailed Memorandum of Understanding could be developed and adopted between the local authorities (e.g. Municipalities) and the responsible governmental institutions (Ministry of Agriculture) to allow for an appropriate implementation of the prescriptions required by the management plan.

Harvest Plan

Table 19. Harvest planning terminology (in reference to FAO 1998)

Terminology	Description
Strategic harvest plan	A Strategic Harvest Plan explains why, where, when and what type of harvesting is proposed. Strategic harvest, planning cannot be undertaken without considering the issues which affect the management of the forest more widely. It is an integral part of a forest management plan, prepared by the planning team, and should never be a separate planning statement that is independent of it.
Tactical harvest plan	A Tactical Harvest Plan is a short-term plan, prepared by a team directly responsible for supervision of harvesting operations, that explains how and who will carry out the operations and when cutting will be undertaken in each annual cutting area. It should be linked through the Annual Plan of Operations with an approved forest management plan and should not be a separate planning statement. A Tactical Harvest Plan is formulated for the operational part of a year, for example, a dry season. It can apply to a single felling area or to a group of separate felling areas.

Types of harvest planning

Planning of wood harvests is one part of overall forest management planning, which is itself a component of comprehensive land-use planning (FAO 1996).

Harvest plans are of two types: strategic and tactical/operational (Figure 17). The strategic harvest plan, prepared by the forest planning team, is a long-term plan that answers the following questions for the forest or concession area as a whole:

- What type of harvesting must be done;
- Why it must be done;

- Where it must be done;
- When it should be done.

The strategic harvest plan should demarcate non-harvest areas, divide the harvestable forest into annual operating areas (harvesting blocks) and design the main transportation system.

The tactical harvest plan, prepared by the team directly responsible for supervision of harvesting operations, is a short-term plan that answers the following questions for each coupe:

- How the harvesting is to be done, in detail;
- Who will carry out the operations;
- When each part of the coupe should be harvested.

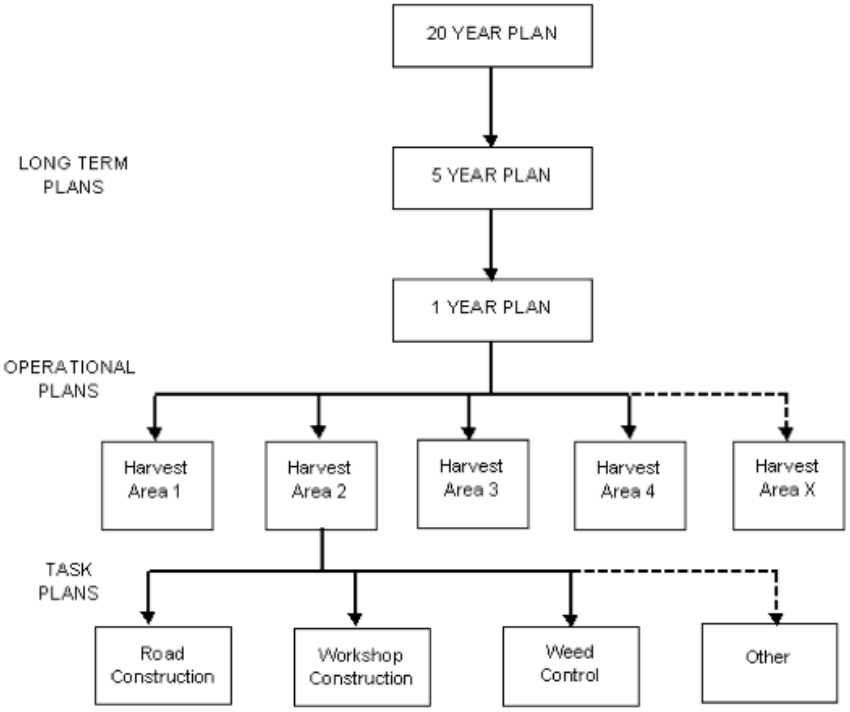


Figure 17. Types of harvest planning (FAO 1999)

Harvest planning cannot be separated from management planning, as both must be done simultaneously by an interdisciplinary planning team. Informative maps and a written plan are elements of a good strategic harvest plan. Maps developed during the preparation for the forest inventory and management plan should show the following features as identified in the forest management plan (Figure 18):

- Forest cover types, important topographic features (preferably with elevation contour lines), streams and both existing and planned infrastructure or other artificial features
- Protection areas such as biological reserves, religious or cultural sites or areas near population centers

- Areas where harvesting is to be carried out, divided into annual coupes or similar areas that can be conveniently referenced on the ground
- Areas where major problems exist that must be overcome when developing the transportation system or in carrying out the harvesting operations. These would include rock outcrops, swamps or other areas of wet soils, important stream crossings and other features
- Areas of non-forest land uses
- Locations of communities that could be affected by harvesting or transport operations.

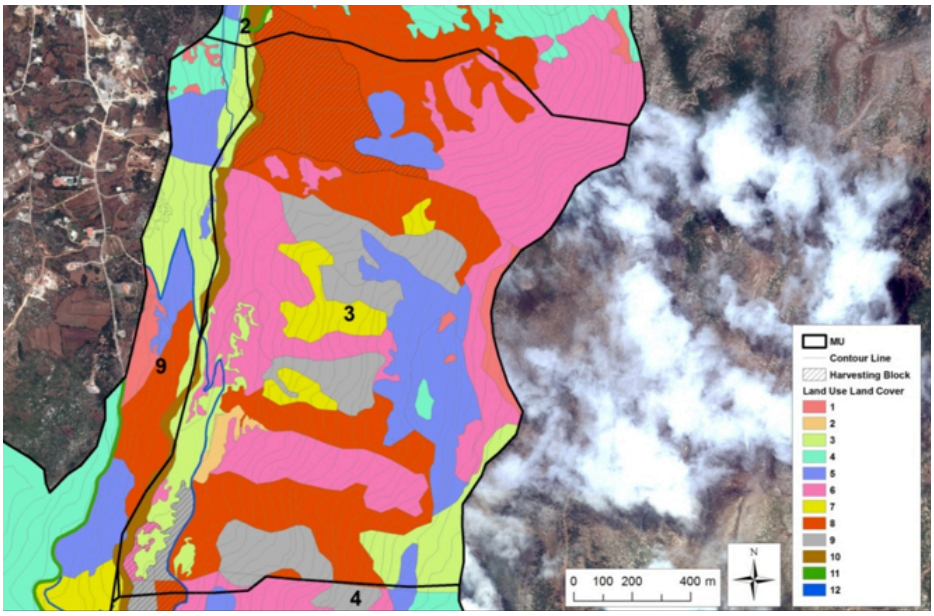


Figure 18. Forest cover map in Andket forest

(1: Rocky areas, 2: Agricultural lands, 3: Herbaceous pastures, 4: Low shrublands, 5: Low-medium shrublands and thicket stage forest, 6: Medium-high shrublands with seed trees, 7: Low pole stage forest, 8: High pole stage forest, 9: Uneven aged forest, 10: Riparian vegetation, 11: Roads, 12: Forest tracks).

The written plan should describe in detail the items shown on the map(s). This plan would typically include the following:

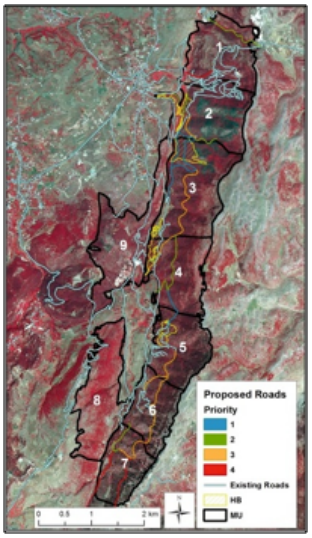
- A description of the planned silvicultural treatments (e.g. pruning, thinning, cleaning, etc...) for each harvesting block or management unit and an explanation as to why each treatment has been selected, including an analysis of the degree to which harvesting is expected to contribute to the attainment of management objectives for the forest
- An estimate, based on a proper inventory, of the volume of timber to be removed from each harvesting block, preferably divided into species or groups of similar species
- A schedule showing the year in which each harvesting block is to be harvested
- Descriptions of any special problem areas noted on the map, with suggestions for overcoming the problems

- A discussion of potential problems relating to local communities and the way these problems have been addressed in formulating the plan
- Detailed information concerning the forest transportation system, such as road design parameters for different conditions (valley bottoms, ridgetops and climbing roads), locations and specifications for major stream crossings, typical spacing and design specifications for drainage structures and other similar information
- Annual labor requirements for harvesting operations and for construction and maintenance of the forest transportation system
- Financial and technical resources needed for harvesting operations in each coupe.

Box 5. Road accessibility in Andket forest

The results indicated difficult accessibility to the different parts of the forest. Accordingly, new roads shall be opened for harvesting purposes. Opening new roads might not be recommended by ecologists, among others. Whether to open or not to open new roads shall be extensively discussed, argued, and agreed on among relevant stakeholders. However, it is essentially important to note that any opening of a new road should be carefully conducted with the main purposes of serving future harvest plans and possibly future firefighting.

For protection and fire prevention purposes, public accessibility on the news roads should be closely controlled and monitored by the Municipality. Such control and monitoring require a long term commitment from the Municipality according to which, permits and licenses to opening shall be released by relevant authorities. Figures below show the road accessibility and proposed roads by priority (Left) and an example of harvesting scheme (Right).



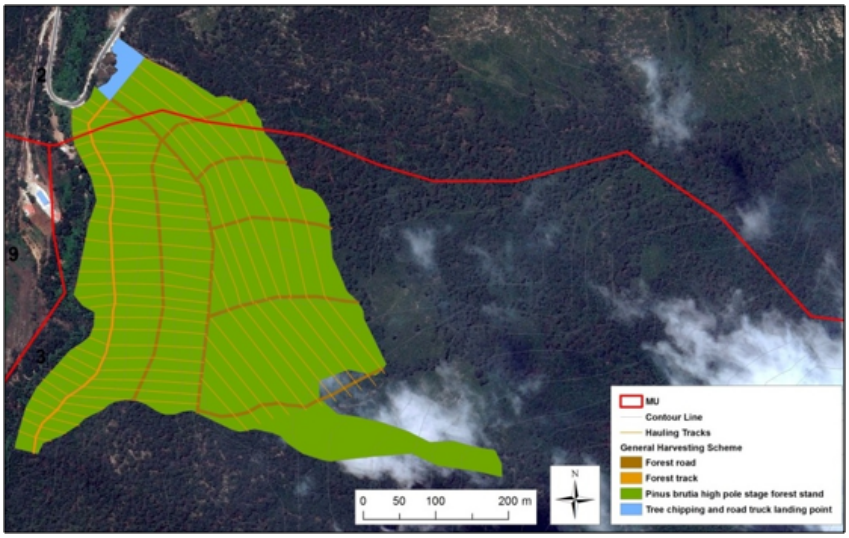


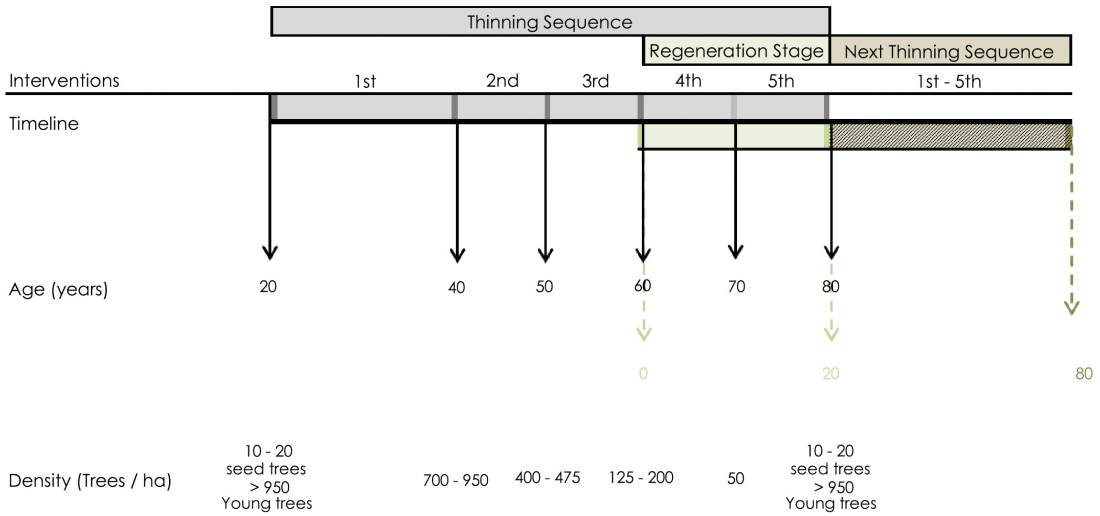
Table 20. Silvicultural prescriptions terminology (SAF 2008)

Terminology	Description
Rotation	In even-aged systems, rotation is the period between regeneration establishment and final cutting —note rotation may be based on many criteria including mean size, age, culmination of mean annual increment, attainment of particular minimum physical or value growth rate, and biological condition (Society of American Foresters –SAF 2008). Rotation in uneven-aged stands refers to time between selective cuttings.
Thinning	A silvicultural treatment made to reduce stand density of trees primarily to improve growth, enhance forest health, or recover potential mortality.
Thinning from below	A type of thinning where the removal of trees from the lower crown classes to favor those in the upper crown classes —synonym low thinning.
Thinning sequence	A term comprising the type, grade, and frequency of thinning for a given area, generally along with their year of commencement and sometimes termination —synonym thinning regime.
Thinning interval	The period of time between successive thinning entries, usually used in connection with even-aged stands —synonym thinning cycle.
Yield management	The amount of wood that may be harvested from a particular type of forest stand by species, site, stocking, and management regime at various ages.
Regeneration cut – Seed tree method	The cutting of all trees except for a small number of widely dispersed trees retained for seed production and to produce a new age class in fully exposed microenvironment —note seed trees are usually removed after regeneration is established.
Pruning	The considered removal, close to or flush with the stem, of side branches, live or dead, and of multiple leaders, from a standing. Generally plantation-grown, tree, for the improvement of the tree (health, non-wood production) or its timber. Live or green pruning refers to the removal of live branches, dead pruning to the removal of dead branches (IUFRO 2000).
Low pruning	Pruning to a specified height or stem diameter in one operation or stage —synonym pruning lift.
Opening or clear cutting	Harvest felling of essentially all trees in a stand or crop (IUFRO 2000)- Example opening forest (hauling) tracks for harvesting operations.
Skidding roads	Roads located in a cutting area and form the outer ends of the haul road network. They provide access for workers and machinery to the cutting area and reduce skidding and forwarding distances. Feeder roads are normally only temporary and are abandoned following logging (FAO 1998).

a) Implementation of silvicultural prescriptions

General models for forest harvesting have been proposed for Mediterranean forest. These included models for Pinus halepensis and Pinus brutia (Beltrán et al. 2011, Cabanillas 2010, De-Miguel et al. 2010, Ruiz-Peinado et al. 2001, Gezer 1985) and Pinus pinea (Piqué 2013, Piqué-Nicolau et al. 2011, Calama et al. 2007, Montero et al. 2004, Ruiz-Peinado et al. 2001, Montero and Canellas 2000). However, the implementation of silvicultural treatments during the period of the harvesting plan (10-years) requires the adaptation to the existing timber stages, tree density and forest structure in the defined management units and identified harvesting blocks. Prescriptions need to be planned in a way to avoid structural instability and compromised natural regeneration. Moreover, prescriptions depend on forest management objectives which include decreasing fire risk and improving forest health in addition to the biomass extraction recommended in the harvesting plan.

Box 6. A generic scheme for silvicultural treatments in Andket's P. brutia forest



b) Human, technical, and financial resources

Data collection on available equipment and labor qualification for the required treatments are necessary to ensure appropriate implementation of the proposed harvest plan and to avoid costly investments. The equipment needed will depend on the silvicultural prescriptions for each specific forest characteristics per management unit or harvesting block. All agencies involved with the management and harvesting of forests should make and implement arrangements for effective training of pruning, thinning and cleaning crews. The aim is to increase and maintain the professional skills, work performance, and work quality of workers, and to develop and maintain an awareness of social and environmental issues. In its simplest form, training can be "on-the-job" guidance on proper silvicultural practices provided by supervisory personnel. It is also desirable that workers attend annual practical courses on safe harvesting practices.

Conclusions and future prospects

This National Forest Biomass Blueprint (NFBP) had two main objectives, namely to:

1. Lay out strategic objectives that will help realize the full potential of Lebanon's forest biomass.
2. Provide necessary guidelines for developing forests inventories, management and harvesting plans towards sustainably meeting those objectives.

The fact that inadequate forest management plans or unsustainable harvesting of forest biomass can pose a threat to forest values including goods and services, best management practices for developing forest inventories, and consequently, forest management and harvesting plans, are widely accepted as necessary tools to ensure the sustainable use of forest biomass.

In Lebanon, tree pruning and thinning in forests can provide relatively large volumes of woody biomass especially from high fire hazard forests, therefore, reducing fire hazard in these areas. Principal sources for woody biomass in Lebanon could be harvest residues, small diameter trees, trees removed for renovation of degraded stands, trees damaged by wildfire, insects and diseases, and short rotation woody crops. Much larger volumes of wood biomass and higher quality wood products could be produced by Lebanese forests with the application of the technical and scientific knowledge provided by the development of a Mediterranean forest science in the last 20 years, particularly regarding close-to-nature management. At the institutional level several cross cutting responsibilities exist between different governmental institutions that deal with forestry. Accordingly, there is a need to establish a coordination mechanism among all these entities in order to ensure sustainable and efficient use of forest biomass. In addition, there is a need to review and update the current legal frameworks that are governing the forestry sector in the country to meet current and future socio-economic and environmental challenges. Overall, the introduction of new legislation or policies and proper incentives to practically stimulate future investments in forest biomass resources is needed.

The main identified strategic objectives that will help realize the full potential of Lebanon's forest biomass includes:

1. Support Research and Development (R&D) investment that will provide foundation for the future management of Lebanon's forest biomass.
2. Promote necessary policy tools, reforms in legislation, and law enforcement.
3. Identify and support opportunities for the development of forest biomass. In this context, it would be essential to be assured through an ongoing commitment to research that forest biomass use will not conflict with conservation and stewardship goals. Capacity building, policy, technology transfer, and market development are considered as key elements in promoting policy tools and reforms in legislation. Also, it is essential to pool needed resources (i.e. financial mechanisms), and knowledge and expertise (i.e. building collaboration and supporting the establishment of public-private partnerships through the involvement of national and local stakeholders) in order to support opportunities for the development of forest biomass.

As for management and implementation, proper forest inventories (providing growth estimations for different site conditions), management plans (multifunctional) and harvesting plans (technically

sound and spatially explicit on yearly schedules) should be developed not only for communal forests but also for the State-owned forests to ensure their sustainability. More specifically, future forest management plans should always include technically-based felling prescriptions to rejuvenate old stands and essentially achieve regeneration by whatever means required (always better if natural, but it can be also acceptable to follow artificial regeneration in certain conditions) and most importantly to preserve best forest conditions under the stated goals. In principle, pruning should not exceed March 15 of each year especially under a changing climate scenario. Yet, new laws are needed to be formulated on the principle of sustainable forest management and conservation of ecosystems and biodiversity in forests and woodlands. Also, Pinus brutia forests should be allowed to be pruned, thinned, and felled based on scientific forest management and harvesting plans to reduce fire hazard in these forests and to promote economic income to local communities.

Pruning permits that are currently given in accordance with the existing regulations in addition to any future pruning permit should be properly monitored. Currently, pruning permits that are given in accordance with the existing regulations are not properly respected; in addition, fines are not properly enforced. More specifically, the fining system should be made more a deterrent, and most importantly, human, financial, and technical resources of the MOA should be improved in order to deal efficiently with suppressing irregularities and simultaneously conducting all tasks related to overseeing, controlling and monitoring of works and investments in forests.

Overall, the development and finalization of a national forest policy or programme remains an urgent necessity to ensure the sustainability of forests and investment and to have forests able to perform their ecological role in light of climate change in addition provide for the increasing societal demand for forest wood and non-wood products. More specifically, a national forest policy and programme needs to importantly address the development of forest inventories as an initial stage to cover the data gaps and to develop national forest management plans. Also, specific forest management plans are required to provide continuity in managerial operations over time, to formalize administrative arrangements and to provide a basis for monitoring forest activities. Finally, strategic harvest plans should explain why, where, when and what type of harvesting is proposed in specific forested areas.

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