Assessing the vulnerability of Mediterranean forests to climate change by using free tools: the case of pilot sites in North African and Near-East countries

Valentina Garavaglia[1], Amine Gacemi[2], Kamel Tounsi[3], Fouad Mounir[4]

[1]FAO –Silva Mediterranea, Italy, valentina.garavaglia@fao.org
[2]Centre of spatial techniques, Algeria, gacemiamine@gmail.com
[3]Sylvo-Pastoral Institute of Tabarka, University of Jendouba, Tunisia, tounsikamel59@gmail.com
[4]Ecole National Forestière d'Ingénieurs, Morocco, mounirf@hotmail.com

Abstract

The multifunctionality of Mediterranean forest ecosystems has long been known. Mediterranean forests are the core of multiple environmental, social and economic practices which include *e.g.* wood and non-wood products, picking, grazing and tourism. However, increasing anthropogenic pressures (*e.g.* urbanization and population growth) and climate change are responsible for degradation of forest ecosystems and consequently for the risk of a reduction in the provision of goods and services. Public policies and local and regional development strategies do not take sufficient account of these aspects. In addition, forest administrations and managers face significant lack of technical and financial support to promote the sustainable management of Mediterranean forest ecosystems.

The type of forest uses in the Mediterranean is very variable in the region. In northern countries forests are mostly privately owned and forest vegetation developed through its natural dynamics driven by the abandonment of agricultural lands. As a consequence of the abandonment, the frequency and risk of fire and the forest dieback process have been steadily increasing. In the southern and eastern countries, forests are often overexploited and these practices contribute significantly to the degradation of these ecosystems.

The need to enhance sustainable forest management practices in the Mediterranean is strictly related to the assessment of vulnerability of those specific ecosystems to climate change. In this context, a regional cooperation project coordinated by the FAO Committee on Mediterranean Forestry Questions - *Silva Mediterranea* and Plan Bleu and funded by the French Global Environment Facility (FGEF), among several activities, assessed the vulnerability of Mediterranean forests ecosystems in five pilot sites of partner countries (*i.e.* Algeria, Lebanon, Morocco, Tunisia and Turkey).

The objective of the analysis is to identify the effects of global changes on the forest cover in the pilot sites in collaboration with local and international experts. The methodology proposed has two main characteristics: i) it promotes capacity building of national experts and ii) it uses

only free data and software. The method produces three main kind of information: i) cartographic material to estimate land-use changes and forest cover changes in the pilot site by using tools developed by the Flemish Institute for Technological Research; ii) vulnerability maps produced using the multifactorial spatial approach developed by the Gesellschaft fur Internationale Zusammenarbeit (GIZ) for the project "Supporting implementation of the United Nations Framework Convention on Climate Change (UNFCCC)" (CCC/GIZ project) implemented in Tunisia; iii) climatic data and climatic projections according to the IPCC Fifth Assessment Report. The results show the current state of the forest cover in the pilot sites and its future dynamic, highlighting the factors driving those main changes. The information produced represents first of all a significant database for each pilot site and will support, in the short and long term, decision making with regard to adaptive management of Mediterranean forest ecosystems to climate change. Some of the results are presented in this contribution other than the regional mechanism that promoted collaborations at local, national, regional and international scale.

1. Introduction

Mediterranean forests are characterized by a remarkable set of features that require careful strategies to implement a sustainable management and conservation (FAO and Plan Bleu, 2013). Global changes like predicted climate and socio-economic changes will exacerbate current threats and require raising awareness of the forestry community to ensure the sustainability of Mediterranean forest ecosystems.

In order to encourage stakeholders to manage and restore Mediterranean forests, a detailed assessment of their current vulnerability is needed. Such studies allow the identification and mapping of main factors affect Mediterranean forest degradation and represent a good starting point to elaborate forest management strategies.

Forecast the vulnerability of forest ecosystems to climate change to the near future, applying IPCC scenarios (IPCC, 2013), will further facilitate a consistent management and conservation.

The present paper shows an example of vulnerability assessment of Mediterranean forest ecosystems to climate change developed by the regional project "Maximize the production of goods and services from Mediterranean forest ecosystems in the context of global changes" (http://www.fao.org/forestry/82782/en/) funded by the French Global Environmental Facility to support the development of tools for decision and management of vulnerable

Mediterranean forest ecosystems and the ability of these forest ecosystems to adapt to global change.

2. Study area

The regional project is implemented in Algeria, Lebanon, Morocco, Tunisia and Turkey where pilot sites have been selected to carry out the activities (Figure 1). The selected pilot sites have different forest areas and ecosystems that are detailed in Table 1.

Figure 1. Pilot sites in Algeria, Lebanon, Morocco, Tunisia and Turkey where the vulnerability assessment of forest ecosystems to climate change were carried out.

Table 1. Characteristics of forest ecosystems in the selected pilot sites.

Name	Country	Total site area	Forest area	Main tree species
Senalba forest	Algeria	62 172	27 820	*Pinus Halepensis*, *Quercus ilex* and *Juniperus excelsa*
Jabal Moussa Biosphere Reserve	Lebanon	6 500	1 250	*Quercus calliprinos*, *Quercus infectoria*, *Platanus orientalis*, *Quercus cerris*, *Ostrya carpinifolia*, *Fraxinus ornus*, *Pinus brutia*
Maâmora forest	Morocco	132 000	126 200	*Quercus suber*, *Pirus mamorensis*, *Eucalyptus* sp., *Pinus* sp., *Acacia* sp.
Siliana forest	Tunisia	91 000	23 500	*Pinus halepensis*, *Quercus ilex*, *Acer monspessulanum*

Düzlerçami forest	Turkey	29 168	17 703	*Pinus brutia, Juniperus excelsa, Pinus pinea, Cupressus sempervirens* subsp., *Cedrus libani*

3. Methods

The methodology proposed was aimed to use free software and data and to promote capacity building at national level, with the collaboration of international experts. The method provides three main kind of information: i) cartographic material to estimate land-use changes and forest cover changes in the pilot site by using tools developed by the Flemish Institute for Technological Research; ii) vulnerability maps produced using the multifactorial spatial approach developed by the Gesellschaft fur Internationale Zusammenarbeit (GIZ) for the project "Supporting implementation of the United Nations Framework Convention on Climate Change (UNFCCC)" (CCC/GIZ project) implemented in Tunisia (GIZ, 2013); iii) climatic data and climatic projections according to the IPCC Fifth Assessment Report.

a. Cartographic material to estimate land-use changes and forest cover changes in the pilot sites

Though many of the steps can be automated, the national experts have an important role in the process shown in Figure 2. The method has to account for the different conditions in each pilot site. In particular with respect to the availability and quality of available reference data, important differences can be expected. Therefore, the national experts must perform a quality assessment of the reference data first. In case quality is poor or reference data are lacking, reference data can be digitized by the national experts. These references will be used for training and accuracy assessment of the results.

For the remote sensing input data, free available Landsat imagery was chosen. Again, it is the task of the national experts to make a selection of optimal images, based on the location of the respective pilot sites, preferred acquisition dates (*e.g.*, during the growing season) and minimum cloud cover. An automatic composite step then combines the selected images to create a single cloud free data set for each reference year (1990, 2000, 2005 and 2010). In addition to the reflectance bands available for Landsat, the normalized difference vegetation index is calculated and used as input for the land cover (change) classification. The whole process is iterated, based on a quality assessment of on the results, conducted by the national experts.

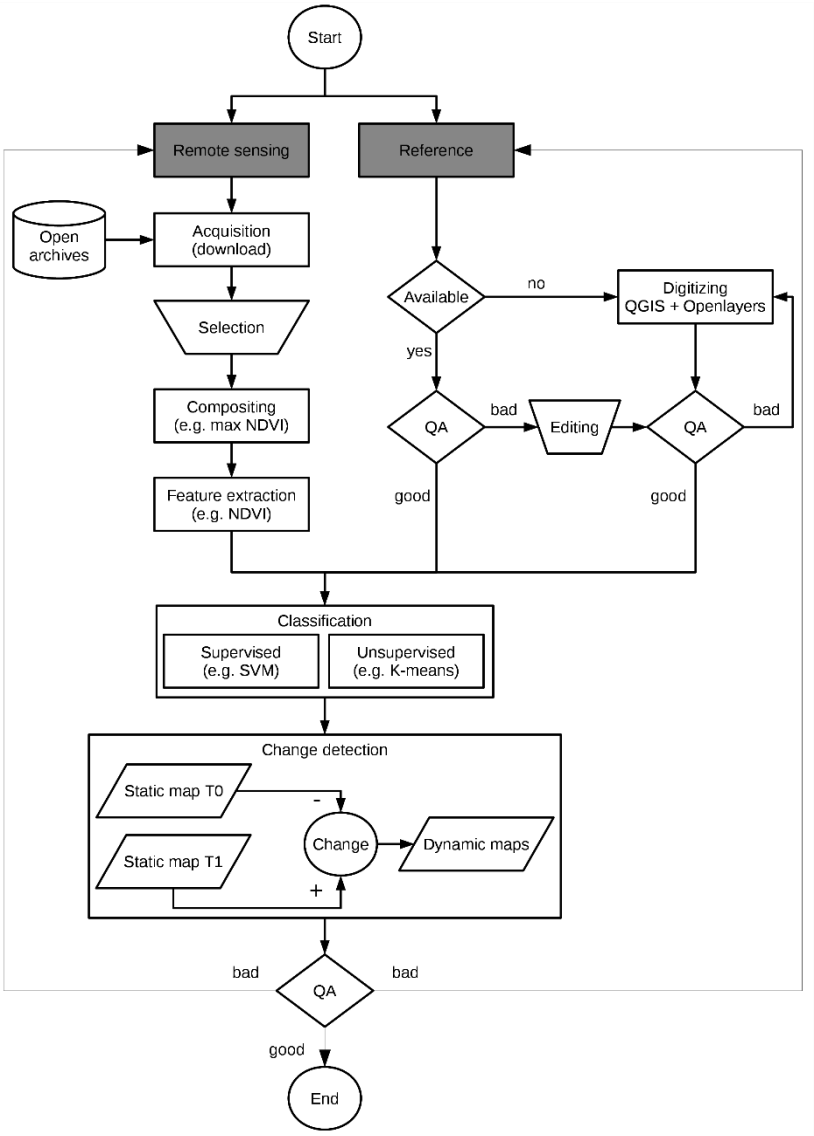

Figure 2. Schematic overview of the method applied to estimate land use and forest cover changes

b. **Multifactorial spatial approach**

The methodology developed by GIZ is a multifactorial spatial analysis that takes into account the complexity of the forest ecosystem by evaluating different factors that characterize it: biophysical, climatic and anthropogenic factors (Fig.3).

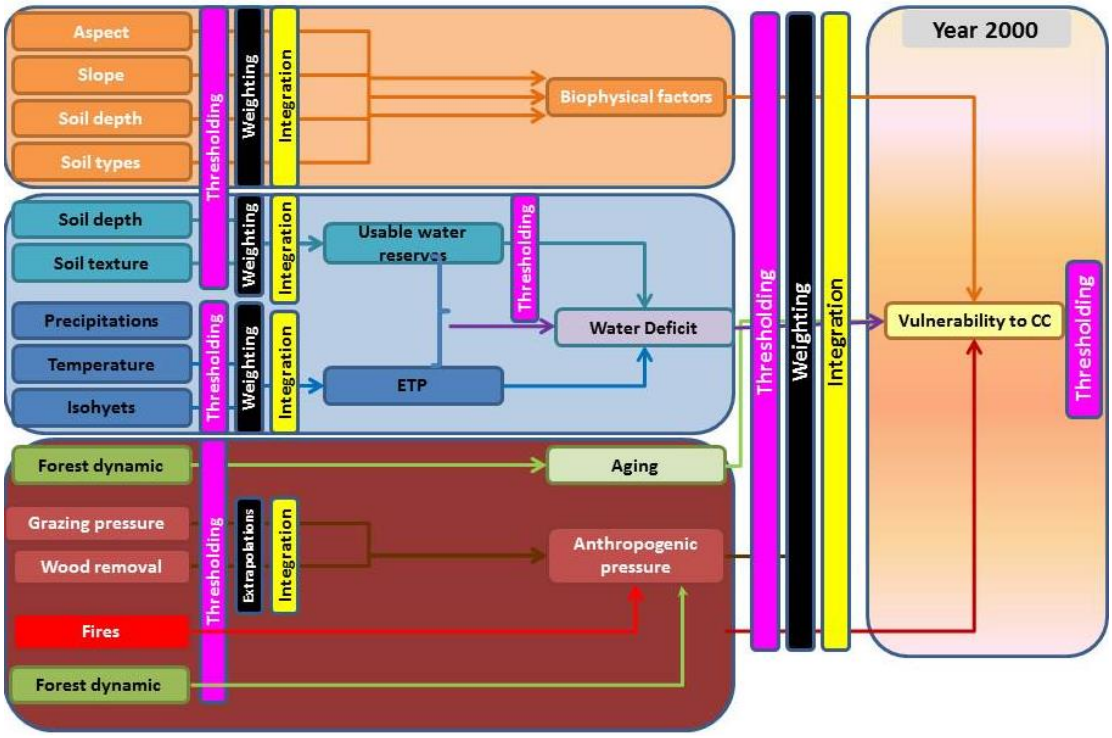

Figure 3. Scheme of the multifactorial spatial analysis applied by GIZ to the Tunisian Aleppo pine ecosystem of the Siliana pilot site

These groups of factors include specific variables and corresponding thematic maps were created showing the vulnerability to each factor in the pilot site.

The thematic maps of vulnerability to biophysical, climatic and anthropogenic factors are then combined to produce a "synthetic" map of vulnerability of the Siliana forest ecosystem in 2000.

The multifactorial spatial approach proposed by GIZ applies IPCC models RCP 4.5 (optimistic) and RCP 8.5 (pessimistic) to the horizons 2016-2036 and 2046-2065 in order to evaluate future dynamics in the vulnerability of the forest cover to the selected biophysical, climatic and anthropogenic factors.

4. Results

Land cover maps in raster format, obtained from remote sensing imagery, can be compared for the different reference years. The raster maps can be aggregated to forest or administrative units resulting in the proportion maps shown in Figure 4. By comparing the results for the reference years, the proportion of particular forest species or land use can be monitored.

The multifactorial spatial approach applied to the Tunisian pilot site of Siliana allowed the identification of the administrative unites (so called "sectors") that in the reference year 2000 were more vulnerable to biophysical, climatic and anthropogenic factors (Fig.5). Figure 5

shows that in 2000 few sectors (in yellow) of the pilot site were little vulnerable to climatic factors and moderately vulnerable to biophysical and anthropogenic conditions.

Future projections to horizon 2016-2035 based on the optimistic IPCC model RCP 4.5 (Fig. 4 right) show significant increases in vulnerability to climatic, biophysical and anthropogenic factors. Several sectors increase their vulnerability to climatic factors, which is also exacerbated by anthropogenic pressures.

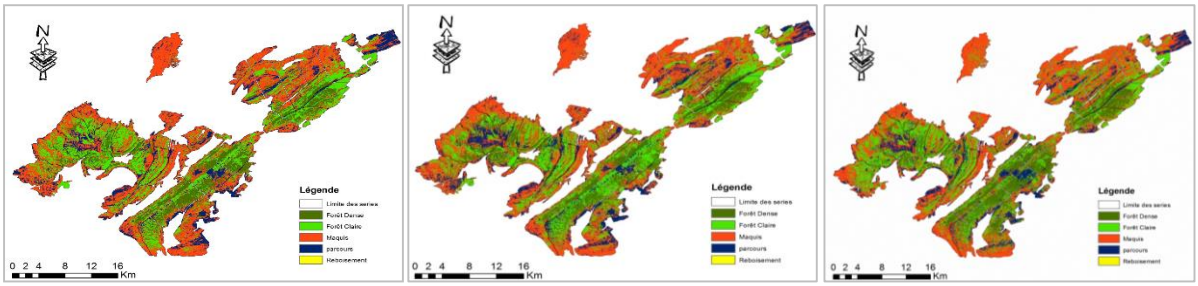

Figure 4. Evolution of the forest cover in the Senalba forest (Algeria) in 2000 (left), 2005 (center) and 2010 (right).

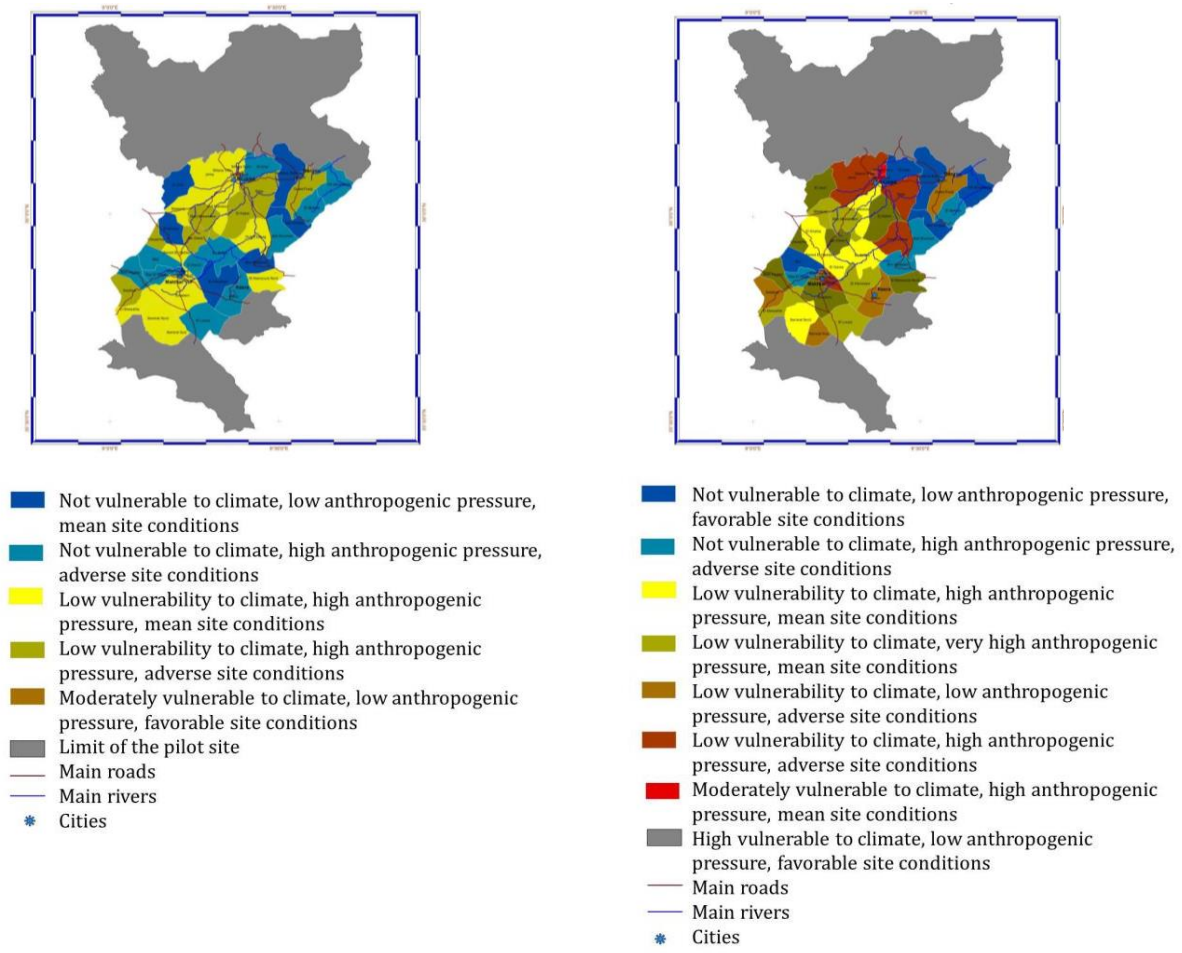

Figure 5. Map of vulnerability of Siliana forest ecosystem to biophysical, climatic and anthropogenic factors in 2000 and for the horizon 2016-2035 (IPCC model RCP 4.5)

Discussion and conclusions

In order to implement innovative and adequate tools to cope with the urgent need of innovative forest management practices that will support the regeneration, restoration and protection of Mediterranean forests, the assessment of current and future state of forest resources at local level is needed. The use of free sources of information and software is an additional asset that facilitates the implementation (and replication) of activities.

The presented methodology combines different tools to create a flexible approach that can be adapted to different forest ecosystems, depending on the available information and on the factors that most influence the forest cover distribution. Based on free data and software is a starting point that creates a useful database for elaborating proposals and supporting decision making with regard to adaptive management of Mediterranean forest ecosystems.

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