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# Modelling, Valuing and Managing Mediterranean Forest Ecosystems for Non-Timber Goods and Services

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Gobierno de España
Ministerio de Ciencia e Innovación

EFI Proceedings No. 57, 2009

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| Publisher: | European Forest Institute |
| Series Editors: | Risto Päivinen, Editor-in-Chief<br>Minna Korhonen, Managing Editor<br>Brita Pajari, Conference Manager |
| Editorial Office: | European Forest Institute<br>Torikatu 34<br>FIN-80100 Joensuu, Finland |
| | Phone: +358 10 773 4300<br>Fax. +358 10 773 4377<br>Email: publications@efi.int<br>http://www.efi.int/ |
| Cover photos: | lamax / www.fotolia.com; Marc Palahí; MEDFOREX photo archives |
| Layout: | Kopijyvä Oy |
| Printing: | Gummerus Printing<br>Saarijärvi, Finland 2009 |
| Disclaimer: | The papers in this book comprise the proceedings of the event mentioned on the back cover. They reflect the authors' opinions and do not necessarily correspond to those of the European Forest Institute. |
| | The Ministry of Science and Innovation of Spain has supported the publication of these proceedings through the Accion complementaria AGL2007-28619-E/FOR |



ISSN 1237-8801 (printed)
ISBN 978-952-5453-27-0 (printed)
ISSN 14587-0610 (online)
ISBN 978-952-5453-27-0 (online)

# Contents

# Executive Summary

Mediterranean forest ecosystems provide multiple non-timber forest products and services which are crucial for the socio-economic development of the rural and urban areas of the Mediterranean region.

On one hand, in the Northern Mediterranean sub-region, the socio-economic changes of the last decades, triggered by the urbanization of our society and better living standards, have lead to an increase in the demand of the social and environmental functions of our forests. This had a positive effect in the economic importance of some non-wood products (pine-nuts, mushrooms, aromatic plants, etc) and different forest services ($CO_2$ sequestration, recreation, nature conservation, etc). At the same time, rural areas have experienced a lack of manpower and a decrease in the profitability of traditional forestry, which has lead to land abandonment and accumulation of forest fuels. This had a strong effect in increasing the risk of forest fires in the last decades.

On the other hand, in the Southern and Eastern Mediterranean sub-regions, non-timber forest products still are relevant primary resources, in particular silvopastoralism, for the subsistence of local economies, while some forest environmental functions (fight against desertification, regulation of the micro-climate, regulating water resources, etc) are key for the sustainable development of these societies.

This framework requires new approaches in forest management and planning as well as in forest policy and economics to address the complexity and multifunctionality of the Mediterranean forests.

The international scientific seminar "Modelling, valuing and managing Mediterranean forest ecosystems for non-timber goods and services" organized by EFIMED and the Universidad de Valladolid (Forestry School of Palencia) in 26–27 October 2007 brought together Mediterranean scientists from relevant disciplines (forest ecology, forest management, applied economics, operations research, and information technologies, etc.) in order to discuss and present the latest scientific methods and results on modelling, valuing and managing non-timber products and services in different Mediterranean countries.

The papers were organized in five main topics to tackle the main scientific challenges in managing Mediterranean forests for non-timber goods and services:

I. Applications of Modelling to non-timber products and ecosystem services
II. Production and economy of cork oak forests
III: Forest management planning for non-timber products and services
IV: Economic techniques to address the management of non-timber products
V: Production of non-timber products: case studies

Such structure provided a unique opportunity to discuss in a multidisciplinary environment key challenges of Mediterranean forestry and forest research.

# Grazing Value of Mediterranean Forests

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## Abstract

Mediterranean forests have a long history of grazing with most of them having developed with the presence of livestock. In the past, several Mediterranean foresters blamed domestic animals, especially goats, for their destruction. Over the last few decades, however, scientific evidence has been accumulated showing that livestock grazing is an ecological factor that can serve the conservation of Mediterranean forests, if properly used. Forage production in the understory varies widely depending on the type of forest, its crown density, past use and site potential. Forage quality, on the other hand, depends on species composition of the understory as well as shade conditions. Removal of understory vegetation by grazing can enhance tree growth due to the reduction of competition for water and nutrients and reduce fire risk. Moreover, it can provide additional income to the farmers and contribute to economic development of a region. Grazing is an important non-timber use of Mediterranean forests with a great ecological and economic value provided that it is properly integrated in their management.

*Keywords: forage production, quality, improvement, livestock, management*

## Introduction

Grazing by domestic herbivores is an old practice in the Mediterranean region. Livestock began to be raised in the eastern Mediterranean in early Holocene, between 10 000 and 6000 BC; by the Bronze Age (3000 BC), they had already spread to the western part, too (Le Houerou 1981). On the other hand, when livestock arrived at the Mediterranean, they replaced wild herbivores which were already grazing there since the Middle Pleistocene (700 000 to 128 000 years ago) and became extinct for unknown reasons (Rackham and Moody 1996).

Since their introduction to the Mediterranean region, livestock became part of the environment with which they evolved together over the centuries. Among ecosystems, forests were the first to be affected either by clearing in order to open up grazing lands or direct grazing to ensure forage in the critical periods of the year. As a result of irrational grazing, a hostile attitude towards livestock was developed by foresters, who blamed domestic animals, especially goats, for destroying the Mediterranean forests and causing soil degradation and desertification (Thirgood 1981; Tsoumis 1985).

In the meantime, it has been realized that mismanagement rather than the mere presence of goats is the main reason for the damage of Mediterranean forests (Papanastasis 1986). Goats as well as other domestic animals can damage forests through uncontrolled grazing (Owen 1979; Huss 1972) and humans should be held responsible for this action (French 1970).

Nevertheless, the ecological role of livestock grazing is not thoroughly investigated yet. With Mediterranean forests facing numerous threats over the last few decades, from global climatic changes and drastic human interventions involving alteration of the traditional land use patterns, overpopulation, abandonment, urbanization and industrialization, livestock grazing should be reconsidered for its role in maintaining diversity and stability as well as for ensuring the welfare of the Mediterranean people.

In this paper, the grazing value of Mediterranean forests is reviewed and methods for its improvement and management are discussed.

## Current situation of grazing in forests

The total area of forests in the Mediterranean countries amounts to about 89 million hectares (Table 1). Not all these forests however are located in the Mediterranean zone. Le Houerou (1981) defined as Mediterranean zone the proportion of the Mediterranean countries which has a xenothermic climate with a mean annual precipitation more than 400 mm and a ratio of summer precipitation to the mean maximum temperature of the hottest month (in °C) less than 7. Based on this definition he provided the respective proportions for each country. By using these proportions, the total area of forests located in the Mediterranean zone (called from now as Mediterranean forests) was found to be about 28 million hectares or about one third of the total forest area in the Mediterranean countries (Table 1).

Mediterranean forests may be coniferous or broadleaved. The former include pine (e.g. *Pinus halepensis, P. pinaster, P. brutia, P. pinea*), cypress (e.g. *Cupressus sempervirens*), fir (e.g. *Abies cephalonica, A. pinsapo*) juniper (e.g. *Juniperus phoenicia, J. excelsa*) and cedar (e.g. *Cedrus atlantica, C. libani, C. brevifolia*) forests. The latter mainly include evergreen forests dominated by *Quercus ilex,Q. rotundifolia, Q. suber* and *Q. coccifera,* but also deciduous forests such as *Q. pubescens, Q. infectoria, Q. faginea, Q. inthaburensis,* etc.

Mediterranean forests are rich in plant species and life forms. Partly because of the light tolerance of the dominant tree species and partly because of their mismanagement in the past, these forests have relatively open crowns. This permits the growth of a lush understory consisting of both herbaceous and especially woody species. The woody plants are mostly evergreen, which means that green leaves and twigs are available throughout the year. As a result, Mediterranean forests constitute an important year-round source of feed for livestock. For this reason, they are also classified as silvopastoral systems because, in addition to forests products (e.g. timber), they also provide forage (Papanastasis 1996).

Goats, among all kinds of livestock, make the best use of the understorey vegetation grown in the Mediterranean forests. This is because, compared to other ruminants, they are superior in digesting organic matter, crude protein and particularly crude fiber, and thus make good use of low protein, high-fiber roughages (Huss 1972).

**Table 1.** Goats and forests in the Mediterranean countries.

| | Goats (thousands) | | | Forests and woodlands (thousand ha) in 1994 | | Goats/ha | |
|---|---|---|---|---|---|---|---|
| Country | 1961 | 2004 | % change | Total | Mediterranean | Total forests | Mediterranean forests |
| Albania | 1104 | 944 | -15 | 1048 | 187 | 0.9 | |
| Algeria | 1946 | 3200 | 64 | 3950 | 158 | 0.81 | 20.25 |
| Cyprus | 149 | 460 | 209 | 123 | 123 | 3.74 | 3.74 |
| Egypt | 772 | 3889 | 404 | 34 | 0 | 114.38 | 0.00 |
| France | 1172 | 1206 | 3 | 15 012 | 2402 | 0.08 | 0.50 |
| Greece | 5064 | 5362 | 6 | 2620 | 1624 | 2.05 | 3.50 |
| Israel | 165 | 75 | -54 | 126 | 84 | 0.6 | 0.89 |
| Italy | 1381 | 978 | -29 | 6809 | 2724 | 0.14 | 0.36 |
| Lebanon | 470 | 430 | -9 | 80 | 80 | 5.38 | 5.38 |
| Libya | 1224 | 1265 | 3 | 840 | 17 | 1.51 | 74.41 |
| Morocco | 7000 | 5359 | -23 | 8970 | 2781 | 0.6 | 1.92 |
| Portugal | 607 | 502 | -17 | 3102 | 1923 | 0.16 | 0.26 |
| Spain | 3300 | 2833 | -14 | 16 137 | 10 328 | 0.18 | 0.27 |
| Syria | 439 | 1018 | 132 | 484 | 174 | 2.1 | 5.84 |
| Tunisia | 550 | 1380 | 151 | 676 | 358 | 2.04 | 3.85 |
| Turkey | 24 632 | 6772 | -73 | 20 199 | 4444 | 0.34 | 1.52 |
| Yugoslavia (Former)[1] | 160* | 344 | 106 | 8652 | 779 | 0.04 | 0.44 |
| Total | 50 134 | 36 017 | | 88 862 | 28 186 | 0.4 | 1.3 |

FAOSTAST archives from the official web page http://faostast.fao.org/site/497/default.aspx
1 Year 1969–71 (FAO Production yearbook, 1978, vol. 32)

There are large numbers of goats in the Mediterranean countries. In 2004, there were about 36 million heads (Table 1). Turkey, Greece and Morocco had the highest numbers and Israel, Former Yugoslavia, Lebanon and Cyprus the lowest. There was a significant decline in the total goat population in the Mediterranean during the period 1961–2008, mainly caused by the considerable decrease of goats in Turkey. Out of the 17 Mediterranean countries, 8 showed an increase, with Egypt and Cyprus registering the highest increases (40% and 21% respectively). This means that goats play an important role in the life and nutrition of Mediterranean people.

Goats, however, are not so great a problem as it is commonly believed. If it is assumed for the sake of comparison that all 36 million goats graze on all forests of the Mediterranean countries then the average stocking rate amounts to 0,40 goats/ha/year (Table 1). This is a rather low figure if it is considered that, for a four-month grazing period, the capacity of Mediterranean forests is estimated at 1.5 goats/ha/year (El Hamrouni 1978; Papanastasis 1981). Even if we assume that goats graze only in the Mediterranean forests, the average stocking rate is 1.3, still below the suggested stocking rate (Table 1). Of the 17 countries, only 6 for total and 8 for the Mediterranean forests exceed this figure, indicating possible overgrazing. These figures, although general and therefore subject to qualification, indicate that goats do not overgraze forests in most of the Mediterranean countries. However, besides goats sheep are grazing in forests with or without goats and in some countries cattle as well. If these animals and especially sheep are combined with goats then overgrazing may occur (Papanastasis 1986).

## Forage production and quality

Grazing capacity of Mediterranean forests is affected by the structure, density and regeneration mode of trees. Structure refers to the age distribution of trees, namely whether forests are even-aged, uneven-aged or mixed-aged. Even-aged forests are potentially more compatible with grazing than the mixed-aged and, especially, the uneven-aged ones. This is because regeneration in the former occurs only in a certain period of their life cycle suggesting that grazing of the understory vegetation can be applied during the remaining time without affecting the young seedlings. In the mixed-aged and especially in the uneven-aged forests, grazing is dangerous to the young seedlings since regeneration is a continuous process throughout their life cycle. As far as density is concerned, open forests are more compatible with grazing than dense ones since the former potentially carry more understory vegetation due to the better light conditions than the latter. Finally, forests regenerated vegetatively (coppice) are potentially more compatible with grazing than the ones regenerated with seeds (high forests) because sprouts are more resistant to grazing than seedlings.

Generally, forage production decreases as canopy cover or density increases. Dense stands carry relatively small amounts of grazable vegetation in the understory. For example, a dense coppice oak forest composed of *Quercus pubescens* and *Q. frainneto,* produced only 1130 kg/ha grazable vegetation consisted of herbs (28%), shrubs (22%) and tree undergrowth (50%) (Vrettakis et al. 2004). This quantity can be increased by opening up the tree canopy.

Papanastasis et al. (1995) found that open stands of *Pinus pinaster* with 300 trees/ ha had significantly higher herbage production than medium and high density stands with 600 and 1200 trees/ ha respectively. A significant increase of herbage production was also found in open stands of *Pinus nigra* plantations and of a coppice forest of *Quercus pubescens* by Msika and Etienne (1989) in southern France. Similar results were found by Matzanas and Papanastasis (2002) in a *Pinus brutia* plantation and by Pantazopoulos et al. (2006) in a deciduous oak forest.

Forage production also decreases with increasing age of forest stands although small increases are seen in early years apparently due to soil preparation for tree planting. For example, Papanastasis (1982) found increased herbage production until the age 5 in a *Pinus nigra* plantation in Greece but thereafter it declined. Without soil preparation however, herbage production is not affected until about the 10th year after tree establishment in *P. brutia* plantations (Platis et al. 1999).

Canopy cover affects seasonal changes of forage production. In a 17 year-old *Pinus pinaster* plantation in Greece, herbage yield was decreased from autumn to winter and increased from winter to spring when it became maximum while the seasonal variation was more pronounced in the open than in the dense stands (Braziotis and Papanastasis 1995). Also, Armand and Etienne (1995) found higher forage production during the winter period under dense (50% crown cover) than open (25% crown cover) stands of *Pinus pinea, Pinus halepensis* and *Quercus suber* in southern France.

Grazing results in reduction of forage production depending on its intensity. In a *Quercus ithaburensis* subsp. *macrolepis* forest, heavy grazing (3.8 sheep/ha) resulted in a 3-fold decrease of understory vegetation (Pantera and Papanastasis 2001). Similar results were found in a *Q. coccifera* forest in Crete where herbaceous and shrubby biomass was decreased by 62% and acorn yield by 86% under heavy grazing with sheep and goats (Papanastasis and Mishah 1998). If shrubs are grown in the understory, then grazing can result in their reduction thus contributing to fire control. In Israel, Gutman et al. (1995) have found that heavy and moderate grazing by cattle in a Mediterranean oak scrub forest resulted in the control of shrubs in favor of herbaceous cover. In a *Pinus nigra* forest in Pyrenees, Casasús et al. (2007) found that a moderate stocking rate with cattle can prevent shrub encroachment and the accumulation of dead material in these forests. Finally, Masson (1999) has found that grazing in the French cork oak forests can result in the control of flammable shrubs such as *Cistus spp., Ulex parviflorus, Erica arborea* and *Calycotome villosa.*

Botanical composition is also affected by canopy cover. Shade seems to favor species or groups of species with different photosynthetic pathways. Cool season grasses (e.g. *Dactylis glomerata* and *Festuca ovina*) are benefited by the presence of trees while warm season species such as *Crhysopogon gryllus* and *Dichanthium ischaemum* prefer more open and lighted areas (Papadimitriou et al. 2004). Also, forbs generally increase under shade but legumes tend to become reduced. Koukoura and Papanastasis (1995) concluded that *D. glomerata* is an ideal species to grow under tree canopy and, among legumes, they suggested *Trifolium subterraneum* as the most suitable.

Nutritive quality of understory vegetation in Mediterranean forests depends on the particular species involved, the kind of forest and its density. Gonzalez-Hernandez and Silva-Pando (1999) have found that oakwoods provide higher quality forage than conifer or eucalyptus stands. On the other hand, *Dactylis glomerata* had a significantly higher crude protein content in the open stands of *Pinus pinaster* as compared to medium and high density stands in the autumn, while in the spring the significant increase appeared only in the medium density stands (Braziotis and Papanastasis 1995).

Browse species are also affected by shade. Crude protein content of leaves and twigs of *Quercus coccifera* was found higher under *Pinus brutia* stands during the growing season, while the concentrations of total non-structural carbohydrates, cell contents and soluble protein were higher in unshaded than in shaded plants. On the contrary, tannin and lignin contents were higher in shaded than in unshaded plants (Koukoura 1988).

Overall, although Mediterranean forests have relatively low forage production and quality compared to the other forage resources, their productivity is more stable and they can be used as strategic resources to complement animal feeding during the critical periods of the year, particularly in the summer period (Talemucci et al. 1995).

## Role of livestock grazing

Although uncontrolled livestock grazing can contribute to the destruction of Mediterranean forests, their controlled grazing can be beneficial. The benefits may be ecological, silvicultural and economic.

In discussing livestock grazing in the Mediterranean forests, Liacos (1980) argues that domestic animals are instrumental to the functioning of these ecosystems because they contribute to nutrient cycling and thus to an increase of their productivity. Because of low temperatures in winter and the lack of sufficient moisture in the summer, decomposition is slow, resulting in the accumulation of organic material on the ground. This can lead to devastating wildfires. Grazing animals can reduce this material and thus prevent forest fires.

The role of livestock in reducing fuel has received special attention in the last few years (Blanchemain 1981; Calabri 1981). Partly as a result of the change in traditional social systems and partly because of policies for exclusion of livestock, especially goats, from the forests in the past decades (Papanastasis 1984), the amount of fuel has increased considerably, resulting in both a higher number of fires and larger areas burned each year. In Greece, for example, the mean annual number of wildfires in forests increased from 724 in 1960–69 to 1701 in 1990–99, while the mean annual area burned increased from 12 377 to 45 161 ha respectively for the two periods (Dimitrakopoulos 2001). Similar trends exist in other countries.

Livestock can also benefit forests silviculturally. Liacos (1980) argues that livestock, by controlling the understorey vegetation, they can reduce the competition with trees for water, which is the limiting factor to plant growth in the Mediterranean environment. Since goats are much more capable than other animals of consuming woody species, they are the right animals to be used. Moreover, they can control sprouts and thus assist in the thinning and management of coppice forests.

Finally, livestock can play an important role by converting organic matter into products such as meat, milk and wool. In the Greek island of Thassos, covered by Mediterranean forests, chiefly *Pinus brutia,* goats and sheep graze uncontrolled for 7.5 months per year. Eleftheriadis (1978), using shadow prices, evaluated the net value of annual forage production in the forests and found that, although moderate, it exceeded the one derived from wood products. It follows that the contribution of Mediterranean forests to the production of meat and milk cannot be ignored, especially in the poor and densely populated countries of the region.

## Improvement and grazing management

Improvement of the grazing value of Mediterranean forests implies manipulation of vegetation in the understory and especially in the overstory, so that both forage quantity and quality are increased. Such an improvement may be carried out with several methods, most of which are also used in rangelands.

*1. Thinning and pruning.* Opening up the tree canopy by thinning is a very effective way to increase forage production in silvopastoral systems with high crown density. This is because more light is allowed to penetrate the crown canopy and reach the understory while the competition for soil nutrients and water is reduced thus favouring the establishment of more forage species. By removing 50 and 75% of the original trees of a *Pinus pinaster* plantation in Greece aged 17 year-old, herbage production was increased by 480 and 1328% respectively two years after thinning (Papanastasis et al. 1995). Increases ranging from 150 to 266% were also found after thinning of *Pinus nigra* plantations and *Quercus pubescens* coppice forest respectively in southern France (Msika and Etienne 1989). Thinning applied in a *Quercus cerris* coppice forest in Italy in order to improve its multiple use including grazing by cattle had very good results (Amorini and Fabbio 1990). If thinning is combined with tree pruning, more light reaches the understory thus further increasing forage production.

*2. Prescribed burning.* Prescribed burning to control dense shrubby undergrowth or accumulated old growth combined with seeding of range grasses and legumes may rejuvenate the system and increase both the availability and the quality of forage production. This technique was successfully applied in *Pinus brutia* forests, both natural and artificial, in Greece and resulted in significant improvement of the grazing value of forests for goats (Liacos 1977; Tsiouvaras 2000).

*3. Fertilisation.* Application of chemical fertilisers in Mediterranean forests may greatly improve forage production. For example, fertilisation with NPK in a *Pinus pinaster* plantation combined with seeding of *Dactylis glomerata* resulted in 6 times higher herbage production than in the control (Papanastasis et al. 1995). In NW of Spain, application of sewage sludge in the understory of a *Pinus radiata* plantation increased herbage production in the spring but reduced legumes in favor of grasses (Lopez-Diaz et al. 1999). If legumes need to be established and enhanced, as should be the case then phosphorous rather than nitrogen fertilisation should be applied. Mantzanas and Papanastasis (2002), however, have found that nitrogen fertilization resulted in a higher understory yield of a *Pinus brutia* plantation than legume seeding and phosphorm fertilization in a wet year while in a dry year the opposite occurred.

*4. Overseeding.* Sometimes overseeding with range species may result in significant improvement of the range value of Mediterranean forests. Open tree canopy is more favourable for establishment of a good pasture by overseeding but closed canopies are more helpful under dry weather conditions (Etienne 1991; Braziotis and Papanastasis 1995). *Trifolium subterraneum* was found to be a suitable species for overseeding in fire-breaks of Mediterranean forests so that a pasture is created for sheep which also control the sprouts of the spontaneous shrubby species thus reducing wildfire danger (Masson and Guisset 1993

*5. Fodder shrubs.* By establishing fodder shrubs in certain types of silvopastoral systems feed is ensured for critical periods of the year thus upgrading the forage value of the systems. This technique has been applied experimentally in the dehesas with very promising results (Olea et al. 1992). Further research is needed as to what extent this method can be applied in Mediterranean forests and at what cost, since establishment of fodder shrubs is an expensive operation.

## Grazing management of forests

Integration of livestock in the Mediterranean forests requires the application of proper grazing management. Such a management involves proper stocking rate, right species or mix of animals and suitable grazing system.

Application of proper stocking rate requires information about the grazing capacity of the forests. Such information though is very limited. Although some forests are highly productive (Leouffre and Meuret 1990; Pantazopoulos et al. 2006), the majority of them have lower grazing capacity than other types of rangelands, particularly grasslands and shrublands (El Hamrouni 1978; Le Houerou 1981). On the other hand, although the dual use of rangelands by sheep and goats results in better utilisation of vegetation, mixed flocks in Mediterranean forests, may not be the best solution (Papanastasis 1986). However, local breeds are more effective users of natural vegetation and they should be promoted in Mediterranean forests.

Proper grazing management in Mediterranean forests is not that easy because of two main difficulties (Papanastasis 1986). One is the need to co-ordinate livestock grazing with forest management which requires that animals should be allowed to graze only a few months each year and perhaps not in all years thus necessitating supplemental feed from other resources. Another difficulty is related with the people who own the animals because they are not always willing to comply with a certain management plan, particularly in the communally grazed areas. To overcome these difficulties, a close co-operation among foresters, range managers, animal scientists and shepherds is needed.

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# The Algerian Forest: Current Situation and Prospects

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## Abstract

The Algerian forest in its totality covers about 4.1 mill. hectares. Confined to the humid, subhumid, semi-arid and arid bioclimatic stages, it accounts for only 11% of the northern part of the country (tellian and steppic areas) where the productive forest occupies 124 900 hectares. In this unit, the cork oak and pine forest with *Pinus halepensis* occupy the majority of the forested areas.

Over the last decades, the effects of drought combined with a demographic explosion and the lack of traditions in forest management and silviculture are the principal causes of forest degradation. Repeated fires, pest and diseases and illegal cuttings caused huge losses to this patrimony, already weakened by the supposed effects of climatic changes. The deterioration of the Atlas cedar forest in Algeria (Aurès mountains, National Parks of Theniet el Had, Djurdjura and Chréa) is one example; it constitutes in itself a major concern for the Algerian foresters and ecologists. Today, research programs are initiated with a view to identify the factors causing and worsening this phenomenon, which affects more than 50% of the cedar forest in the Aurès. Moreover, the over-running of natural cork oak forest, in particular by *Pinus halepensis* in the centre and in the west of Algeria, and by *Pinus pinaster* in the coastal and eastern parts.

Many actions are carried out by the forest administration aimed at protecting the forest and conserving its biodiversity, such as the creation of national parks, regional nature reserves and the so called integral reserves. In parallel, ambitious national programs of afforestation were initiated, at a rate of 60 000 hectares per annum. In addition, the propagation of exceptional and rare species is tested for their preservation and conservation.

*Keywords: Algerian forest; biodiversity; deterioration; afforestation; climate change*

## 1. Introduction

The future of our forests constitutes a major stake for the country. The current mobilization of the civilian society, through many associations aiming at protecting the environment, clearly reflects the interest of the population for its forest patrimony and environment.

The principal functions assigned to our forests are as follows: protection and soil conservation, regulation of climate and water courses, reduction of pollution, the creation of wealth by the socio-economic development of the forest-related populations, etc. The forest constitutes also the last habitat for various and exceptional animal species, and an area for recreational activities increasingly requested by the citizens. The fact that the Algerian forest is subject to constant human and pastoral pressure, combined with the increasingly severe climatic conditions (in particular the drought of these last year), makes it more fragile and vulnerable. In Europe, it is quite the opposite which occurs, as the Mediterranean forests tend to re-settle territories abandoned by rural activities (Bonnier 2005).

Although the Algerian forest accounts for only 2% of the surface of its territory, it is the only ecological and floristic barrier which protects us from the advance of the desert.

The Algerian forest and woodlands cover 4.1 mill. hectares, of which 1 902 000 hectares are maquis and shrubby land accounting for 46% of the total surface. The forest sector is under the authority of the forest administration (Directorate-General of the Forests: DGF) which is in charge of preserving, conserving and sustainably managing forest and woodlands for the present and future generations. Research activities are coordinated by the National Institute of Forestry Research (INRF). Many programs and initiatives are implemented for providing the bases of Sustainable Forest Management (SFM), with the objective to meet the social and economic needs, in particular of the populations depending directly on the forest patrimony.

The management and use of our forests on the short, average and long term will depend on an increasing range of users (dwellers, users of the dead wood, timber and cork, farmers, public sector, etc.). The main question which will be necessary to know is how to conciliate the various interests without damaging the natural resource.

## 2. Distribution of the Algerian forest

Algeria is divided into three great geographical sets: chains of the Tellian Atlas in the North and the Saharan Atlas in the South separated by the zone of the Higher -plateaus. The Algerian forest is distributed especially in the northern part of the country where the ecological conditions, especially climatic conditions, are favorable and allow the occurrence of various woody species. In general, the Tellian Atlas benefits from a Mediterranean climate with soft winters and a period of summer drought during three or four months (Zéraia 1981; Barbéro et al. 2001; Messaoudene 1989; Merbah 2005). The Higher-plateaus and the Saharan Atlas are characterized respectively by semi-arid, arid and Saharan bioclimates marked by long periods of aridity with great thermal variations. The temperatures of the Tellian zone oscillate between 5 and 15°C in winter and 25 to 35°C in summer, whereas in the South the temperature can reach more than 45°C.

The forest is primarily composed of conifers such as Aleppo pine (*Pinus halepensis*), cedar of Atlas (*Cedrus atlantica*), maritime pine (*Pinus pinaster*), thuja (*Tetraclinis*), juniper-trees (*Juniperus*) and of leafy -trees represented by cork oak (*Quercus suber*), holm oak (*Quercus ilex*), zeen oak (*Quercus canariensis*) and afares oak (*Quercus afares*), and many species of eucalyptus and ash (*Fraxinus*), etc. (Table 1).

**Table 1.** Principal forest types and areas in Algeria.

| Species | Surface (ha) | Rate (%) | References |
|---|---|---|---|
| Aleppo pine | 881 000 | 21 | 1 863 858 ha (DGF 2005), 852 000 ha (Boudy 1955), 1 082 000 ha (PNDF 1984) |
| Cedar | 16 000 | 1 | 45 000 ha (Boudy 1955), 23 000 ha (Bentouati and Barriteau 2006) |
| Maritime pine | 31 000 | 1 | 38 000 ha (Khelifi 2002), 57 727 ha (DGF 2005) |
| Cork oak | 230 000 | 6 | 480 000 ha (Saccardy 1937; Boudy 1955) |
| Holm oak | 108 000 | 3 | 354 000 to 680 000 ha (Boudy 1955; Kadik 1983; Letreuch 1991; Dahmani 1997). |
| Zeen and Afares oak | 48 000 | 1 | 65 000 ha (Messaoudène 1989) |
| Eucalyptus | 43 000 | 1 | |
| Afforestation for protection | 717 000 | 17 | |
| Maquis and bushwoods + empty areas | 1 902 000 | 46 | |
| Other items (thuya, juniper-trees and ash-trees) | 124 000 | 3 | |
| S/total Forests | 4 100 000 | 100 | |
| Alfa (esparto) lands | 2 600 000 | 100 | |
| General Total | 6 700 000 | 100 | |

Because of the absence of recent forest national inventory, it is difficult to know the exact state of the Algerian forest formations and their production. The available data differ from author to author. However, the comparison between the current data of the forest administration (DGF 2005) and the data of the old and recent literature shows that the area of Algerian forest has significantly decreased, and the principal forest types, except the pine forest with *Pinus halepensis* and *Pinus pinaster,* show regressive dynamics. It appears that Holm oak forests, according to the data of Boudy (1955), Kadik (1983), Letreuch (1991), Dahmani (1997) and Khelifi (2002) has lost between 15% to 30% in area, and the cork oak compared to Saccardy (1937) and Boudy (1955) 52%. The degradation of cork oak forest has resulted in the extension of Aleppo pine forest (*Pinus halepensis*) in the middle-west of Algeria and maritime pine (*Pinus pinaster*) in the center-east, and in the coastal area stretching from Jijel to Oum Tboul (El-Tarf), with an increase from 38 000 ha (Khelifi 2002) to 57 727 ha (DGF 2005). The rate of loss in area of cedar stands exceeds 60% if one refers to Boudy (1955) and 30% if one refers to Bentouati and Bariteau (2006) who mention surfaces of 45 000 ha and 23 000 ha respectively. The regression rate is at present more important if one takes into account the important decline in the Aurès and the surfaces devastated by recent fires in Djurdjura. The zeen oak and the afares oak regressed 26.6% compared to the surface given by Boudy (1955) and Messaoudène (1989).

Since the 1980s, Algeria has reforested many areas with Aleppo pine, several species of eucalypts, maritime pine and pine of Canary Islands, totaling 760 000 ha.

Although it is subject to continual aggressions related to man and climate, the Algerian forest has resisted in some areas. Today, the forest patrimony contains very beautiful forests with, in general, a regular structure and a high stocking. This is the case with deciduous oak stands (Akfadou, Aït Ghobri, Béni-Salah, Ain Zana, Taza, etc.), of cedar stands (Tikjda and Tala Guillef in Djurdjura, Belezma (Aurès), Chréa, Thaniet El Had and Babors), of many pine forests (Khenchela, Djelfa, Telagh) and of cork oak forests in Mechrouha (Souk-Ahras), Tizi-Oufellah (Aït Ghobri), El-Tarf, Bouchegouf, Collo, Skikda and Jijel). The productive forests with a significant economic role are composed of the following species: Aleppo pine, maritime pine and cedar for the coniferous trees, zen oak and afares oak, cork oak, eucalyptus, alder, poplars and ash for the deciduous trees. The protective forests are composed of holm oak, kermes oak, thuja and juniper trees.

## 3. Production and products of the Algerian forest

If we consider only the productive stands, the Algerian forests have a low productivity: it is about 1m$^3$/ha/year, corresponding to an annual increment of 1.2 m$^3$ for all species, of which Aleppo pine alone contributes 80%. The national inventory of 1984 provides an estimated standing volume of 54 955 000 m$^3$ of which 30 437 000 m$^3$ is of Aleppo pine. The annual production of wood (harvest) has been very irregular since the independence of the country. It has been very low from 1963 to 1990. On the other hand, It has increased significantly since 1991 culminating in 1993 with 240 000 m$^3$ (FAO 2007). Because of the small productivity, the state imports more than 85% of its wood requirements, material intended for multiples uses: construction, joinery, cabinet work, etc. The objective of the forest administration is to encourage the exploitation of the local resources and to annually mobilize more than 500 000 m$^3$ of timber in the coming years.

The degradation of the cork oak forest has considerably influenced the production of cork and its market in Algeria. For 2006, the production of various category of cork is of 72 952 quintal, which remains very far from the evaluated national potential of 200 000 quintal/year (Metna 2003). Though this fall of production is due to the reduction in the surface of the productive cork oak stands, it is also related to the lack of proper management of the remaining forest, the inaccessibility of the areas subject to exploitation, the lack of skilled manpower in the sector and the absence of technical knowledge of the owners.

In Algeria, the development of the cork industry has expanded remarkably since 1990. Cork has become a highly demanded and multipurpose material: the stopper industry, interior furniture, decoration, shoes and insulation industry. The new uses and the great demand have considerably influenced the cork market. As an indication, the price of one quintal cork fluctuated between 41 euros for burned cork and 150 euros for the healthy so-called reproduction cork in 2007. Till now, more than 20 units of cork transformation have been created in Algeria whereas before, the monopoly was held by only one official company (ENL: National Company of Cork). The recent rising interest for cork has caused turmoil in the market and increased unfair trading. In order to improve the rational management and sustainable development of cork oak stands, the standardization, classification and certification of its products, the Inter-professional National Commission of cork (CNIL) has been installed in 2007.

The stands of zeen oak and afares oak with an surface area of 48000 hectares could alone provide an annual harvestable production of more than one million m$^3$ (Messaoudène 2006). The improvement of production and of quality of their wood is possible if adequate silvicultural treatments are applied. The objective is to eliminate the growth stresses which

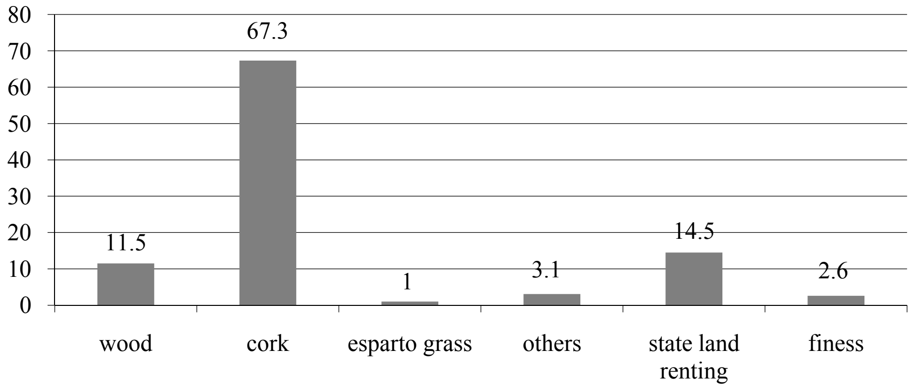


**Figure 1.** Incomes in percents of the Algerian forest (FAO 2003)

impact negatively on the physical and mechanical properties of their wood (Tafer 2000). This could be achieved if sound research is undertaken. So from immemorial times, the wood of these two oaks is considered as of poor technological quality just because these forests were never managed, nor received a necessary silvicultural care. This has led to a restriction in the use of these oaks to railroad sleepers, poles and construction material. However, certain craftsmen could use these oaks as parquet floor, circumference of sieves, joinery and craft industry. It can also be engineered into laminated materials. The wood of other oaks (green and kermes) is used more as firewood. There are still some charcoal manufacturers who supply ironworkers and restaurants.

In addition to the woody products, the forest offers other goods and services which are still badly marketed either due to ignorance or cultural tradition. This is the case of mushrooms, for no less than 54 species of edible mushrooms have been inventoried just for the forest of Akfadou (Kabylie) made up mainly of oaks (Ferrahi 2004). However, the gathering activities are done only by some experts, leaving this fungal potential unexploited. An emerging activity which is practiced on a small scale is the collection of condiment, aromatic or decorative species like the noble bay-tree (*Laurus nobilis*), thyme (*Thymus numidicus*), the origan (*Origanum glandulosa*), the young and adult asparagus stems (*Asparagus acutifolius*). The stump of *Erica arborea* is especially used for firewood or for pipes handicraft.

The esparto (*Stipa tenacissima*) production, with an average harvest of 30 000 t/year in the early 1990's, is only of 10 000 t/year since 1994 (FAO 2003). The cause of this regression is mainly due to the degradation of the alfa area by the pastoralism, the disaffection of the operators and the rarefaction of the manpower. This fall has a considerable impact on certain activities, in particular the craft industry of alfa and paper industry. This latter uses in parallel the wood of eucalyptus (*E. camaldulensis, E. globulus, E.grandis, E. gomphocephala, E. leucoxylon*), a species introduced for this purpose. The intensive afforestation programmes of eucalyptus in Algeria began around 1975 especially in the regions of Annaba (16 310 ha), Guelma (3940 ha), Skikda (2845 ha), Tizi-Ouzou (6070 ha). With a total area of 43 235 ha, these stands can provide an annual production of 144 800 $m^3$/year.

The income obtained from the Algerian forest is estimated at more than 640 million DA for the year 1999. The share of cork and wood accounts for 78.8 % of the total income (Figure 1). Even if this income is significant for the local economy, it is still low when compared with the GDP of the country which was 3168 billion DA. We think that this income can be increased by the valorization of other products and by-products of the forest.

## 4. Conservation and protection of resources and ecosystems of interest

Algeria is a country rich in plant resources, and no less than 3200 species were indexed in its flora, of which 640 are rare and 168 species are endemic. Among the threatened species registered on the red list of IUCN (the international organization for nature conservation), some remarkable species are to be found: the Tassili Cypress (*Cupressus dupreziana*), endemic species of the central Sahara which is represented by a few hundred of individuals in the national park of Tassili, the thuriferous juniper (*Juniperus sabina*) and the black pine (*Pinus mauritanica*) in Djurdjura and the fir tree of Numidie (*Abies numidica*) in Babors. Other species such as yew (*Taxus baccata*), *Acer campestris, Acer monspessulanum, Acer obtusatum, Acer opalus, Populus euphratica, Sorbus torminalis, Pistacia atlantica* and *Olea laperrini* are also protected.

In addition to traditional protection of the forest and the vegetation types trough conventional forest management, protected areas are created in order to preserve and protect valuable plant and animal habitats from the strong demographic pressure and from all forms of aggression. These ecosystems are of great interest because of their biodiversity, originality of landscapes and vulnerability. Since 1970, the country has paid a very particular attention to the protection of these areas. This policy continues today based on national texts, conventions and international agreements that Algeria ratified, concerning the protection and conservation of natural resources.

There are actually three types of protected areas: National Parks, hunting areas and natural reserves. It is also envisaged to create natural parks, another category of protected areas which will ensure the socio-economic development of populations and environmental protection. The forest of Akfadou in the wilaya of Béjaia and Tizi-Ouzou, the complex of wetlands of Guerbès/Sanhadja in the wilaya of Skikda and the forest of Zana in the wilaya of Souk Ahras are currently subject to studies for their classification as natural parks.

Currently, the forest administration manages 10 national parks which total 165 362 ha, that is to say 0.07% of the national territory. They are mainly located in the northern part of the country. Five of them are classified as reserves of biosphere. As for the natural reserves, six sites of 67 000 ha are proposed to be classified.

Other zones are also put under the state protection, they relate to all the wetlands of Algeria such as lakes, sebkha, gueltas, marsh, oasis. Since its adhesion to the convention of RAMSAR in 1982, Algeria has recorded thirteen wetlands of international importance particularly for the protection of the sites of passage, rest and reproduction during the water birds migrations. It is more than 1.8 million hectares of surface (DGF 2001). As for the hunting areas, created mainly for the protection and the development of the local wildlife potential, there are four reserves with an area of 50 700 ha.

In addition to these few types of protection, a number of arboreta were created to enrich the forest with new indigenous species able to adapt to our areas and mainly, to meet the needs for the programs of afforestation initiated by the forest sector. All these various measures taken in favor of the biodiversity preservation are expected to increase in the years to come.

## 5. Factors of degradation

Like in other Mediterranean countries, the Algerian forests are subject to various hazards and more particularly those related to human activities. Impact of man on the Algerian forest ecosystems has dramatically increased over the recent years. It has led to an alarming regression of forest stands and thus of their biodiversity. Obviously, other factors such as climatic changes and aridity of the climate since the 1980s threaten the Algerian forest. This aridity could be the causing factor of the deterioration of cedar forest in the Aurès and is obviously linked to fire occurrence. The drought increased the level of combustibility and flammability of plants, the particular topographic conditions of most of Algerian forests which are situated on steep slopes and with a limited road network increased fire propagation. Though these natural factors played a role, one could recognize that the degradation of our forests results also from the absence of a forest policy in Algeria, aggravated by the absence of management and silviculture and the absence of modern means of fire control.

The fires are undoubtedly the most important factor of forest degradation. The analysis of data on fires evolution in Algeria from 1963 to 2007 (Figure 2 and Figure 3), shows that the average burnt surface per year is of 33 111 ha. Globally, the surface burnt each year varies from 2503.43 ha (1966) to 271 597.79 ha (1995). The 1980s and 1990s were affected severely by forest fires with burnt surfaces of 380 588.38 ha (1980) and 521 503.38 ha (1990). The total burnt surface from 1963 to 2007 reached 1 490 032.19 hectares.

Another cause of forest degradation in Algeria is overgrazing. One can estimate that the load of domestic animals quadrupled in forest stands between the 1950s and 1980s; the problem is that the herds' needs are higher than the fodder availability in the zones of pasture, especially in summer. This situation leads the shepherds to use the foliage of woody species as food complement.

In relation to plagues, principal destroyers are the processionary caterpillars (*Taumétopea pityocampa*) on the pines and *Taumétopea bonjeani* on the cedars, *Phoracanta semi punctata* on the eucalyptus and *Lymantria dispar* for the oaks. These insects weaken the trees if the attacks are repeated, but the effects are visible only several years afterwards. In Algeria, the Directorate-General of the Forests in collaboration with the National Institute of Forestry Research has set up a national forest health survey service in charge of observing and warning of the devastators of the forests. The principal missions are: the selection and installation of observation plots in the forests which present risks; the regular assessment of the plots, and infested areas, the recommendation of the methods of control appropriate to each type of pest, and the planning and supervision of chemical treatment operations.

The other factors of forest degradation are the illegal cuttings and some housing on forest lands. To satisfy their wood requirements for construction and fire (wood alive or dead), neighboring populations quite often use the forests. In addition to the volumes of wood officially sold or yielded free, the volume of illegal cuttings in the forest can be evaluated as double.

The use of the forests as uncontrolled waste disposals and dumps, the anarchistic exploitation of the stone quarries inside the forests are new factors worsening the degradation of forest lands and landscapes. In general, these dumps are the starting points of fires in forests.

## 6. The Algerian forest: challenges and prospects

The Algerian forest is subject to various forms of exploitation and uses. Degradation and loss of forest ecosystems are exacerbated by the growing demand and need of a developing. In order to preserve and reconcile the various forms of use of the forest, the main challenges are to:

- develop the multi-functions assigned to the forest in order to reinforce its role of protecting the environment and allowing local development;
- find the mechanisms which will allow to reconcile; economic development, well-being of populations and conservation of the forests;

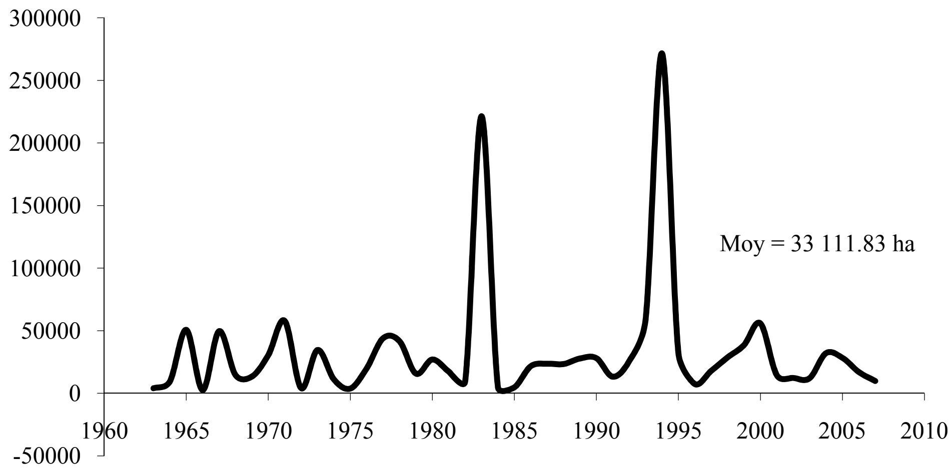


**Figure 2.** Annual area (ha) burnt in Algeria from 1963 to 2007, the annual average is 33 112 ha (DGF 2007)

- guide and help the population in developing programs to upgrade the value of forest products and by-products;
- reinforce the knowledge on the productive and protective capacities of our forests by studies of inventory and reasonable and durable forest management;
- develop ecotourism activities in forest areas; and
- develop the wood and cork industry and to make it economically efficient, by the creation of a commission composed of the forest administration and various private users.

In addition to the importance of protection and maintenance of the existing forest capital, the plans of the forest sector (DGF 2004) for next years are as follows:

- Establishment of National Forest Land Register.
- National Forest Inventory: complement and correction of computerized data bank from 1978 to 1984, using data from forest formation maps, development of computerized cartography and national plan for forest development.
- National Afforestation Plan (PNR): it is designed for a period of 20 years and will aim at the conservation and extension of the forest patrimony, the treatment of the watershed in mountainous zones, the fight against soil degradation in arid and semi-arid regions and the creation of jobs. These are thus 1245900 hectares which will be concerned with various actions (afforestation, fixing of banks, installation and opening of tracks and forestry infrastructure, etc.) which will be carried out over the next 20 years and which will change the proportion of forest cover from 11 to 13%. Between 2000–2006, 112 551 ha were planted i.e. 18 758 hectares per year.
- Development of a strategic plan of sustainable management of forests, treatment of watersheds and development of mountain areas.
- Rehabilitation of the Algerian cork forests.
- Development of esparto on an area of 2.6 million hectares.
- Intensification and improvement of infrastructure network and forest equipments.
- Fight against erosion, desertification and drought, in particular by consolidation and extension of the Green Dam (Barrage Vert) on an area of 3 million hectares.
- Development of local forest police close to rural communities and integration of the citizens in management and sustainable forest development: financial assistance to local

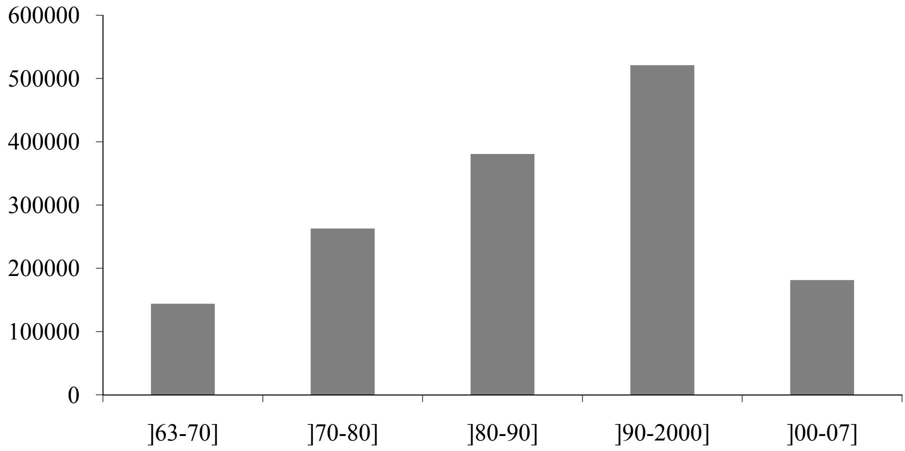


**Figure 3.** Surface (ha) burnt in Algeria per decade from 1963 to 2007 (DGF 2007).

populations through the National Fund FNDRA and sensitizing the population to fires and its effects on the environment.
- Search for partnership with the countries presenting the same concerns of conservation and forest development.

## 7. Priorities for forestry research

Taking into account the forest context and environmental changes which take place at the scale of the Mediterranean Basin, the priority topics of the Algerian forest research lie within the scope of many national and international research agendas. The programs under consideration by the three units of research of National Institute of Forestry Research (INRF), until 2010 will address the following topics:

- Functioning and spatio-temporal dynamics of the steppe, saharan and tellian forest ecosystems.
- Installation of a monitoring network on climatic changes and on main forest insects and diseases.
- Study and research on the causes of deterioration of the Algerian cedar forests and on the prospects for restoring degraded stands.
- Search of strategies and approaches for the rehabilitation of cork oak forests.
- Promotion of forest products, by-products and non-wood forest products.
- Management and silviculture of coniferous and deciduous stands.
- Improving the techniques of seedling production and plantation.
- Creation and organization of a certified seed bank.
- Selection and improvement and multiplication of species of economical interest.
- Searching, testing the local seed source resistant to drought.
- Assessing and monitoring the desertification.
- Quantification of erosive phenomena and control methods.
- Planning and improvement of production systems in mountains.
- Sustainable management of agro-pastoral resources in steppes.

## 8. Conclusion

Like all the countries of Mediterranean basin, the Algerian forests will be subject more and more to the climate risks, characterized by irregular rains which are unevenly distributed in time, and by increasingly rising temperatures, mainly in autumn and winter. In addition, the important population pressure, characterized in the case of the forest settlements by an important urbanization and a socio-economic development of the populations, will generate pronounced degradations of the already weakened forest patrimony. In spite of the efforts and financial means engaged in the conservation of our forests, significant forest areas of great importance for the ecological balance of the country are lost year after year. The forests managers, the organizations in charge of the environmental protection must work in concert in order to sensitize and educate the civilian society, as this is the only guarantee for the protection of our forests.

## Acknowledgements

We would like to thank particularly Dr. Carlos Gracia (CREAF, University of Barcelona) for checking this paper and for all his help before and after the 1st Annual Seminar of EFIMED and the EFIMED organization.

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# Modelling the Production of Wild Mushrooms in Scots Pine (*Pinus sylvestris* L.) Forests in Catalonia (North-East of Spain)

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## Abstract

Mushroom picking has become a widespread autumn recreational activity in the Central Pyrenees and other regions of Spain. Predicting mushroom production based on forest stand and site characteristics is required if mushroom production needs to be considered as a management objective in forest planning. This study used mushroom production data from 24 Scots pine plots over 3 years to develop an empirical model that could facilitate forest management decisions when comparing silvicultural options in terms of mushroom production. Mixed modelling was used to model the dependence of mushroom production on stand and site factors. The results showed that productions were greatest when stand basal area was approximately 20 $m^2$ $ha^{-1}$. Increasing elevation and northern aspect increased total mushroom production as well as the production of edible and marketed mushrooms. Increasing slope decreased productions. The annual variation in mushroom production correlated with autumn rainfall.

*Keywords: multiple-use forestry; forest management; non-wood forest products; mixed models; Lactarius deliciosus*

## 1. Introduction

Traditionally, forests have always provided multiple products and services for society. However, with the increasing exodus from rural areas and urbanization of society, the rising incomes and environmental awareness of society, the importance of non-wood forest products and of the social and environmental functions of forests have increased as never before while the profitability of traditional forestry have dramatically decreased (Mogas et al. 2006).

In this context, wild edible and medicinal mushrooms represent an important non-wood forest product world-wide (Boa 2004) to the extent that the commercial value of forest fungi may equal or even surpass the value of timber (Alexander et al 2002; Arnolds 1995; Oria-de-Rueda 1991). Consequently, there is a growing interest on the part of forest owners and managers to inventory, predict, and manage to improve the production of marketed mushrooms (Pilz and Molina 2002).

Recent inventories of wild mushrooms from *Pinus sylvestris* forests of the Prepyrenees of Catalonia report productions of approximately 60 kg $ha^{-1}$ fresh weight (Mártinez de Aragón et al. 2007) of which 54% are edible species, 29% are marketed species and the other 25% are edible but not marketed species (Bonet et al. 2004).

Mushrooms are not only a source of income for the collectors and tourism businesses but may soon provide an economic incentive for the forest landowners. A recent survey demonstrated that Catalonians are willing to pay for the experience of picking wild mushrooms (Mogas et al. 2005). Consequently we could expect incentives for improved forest management.

Site and growing stock characteristics are the most reasonable predictors when developing an empirical mushroom production model for forest planning because the site and stand characteristics are known factors. In addition, stand characteristics can be altered through forest management. However, mushroom productions also depend on weather conditions such as the timing and quantity of rainfall, which are not equally useful in forest planning because they cannot be accurately predicted beyond a few weeks.

The construction of reliable models for predicting mushroom productions requires collecting large quantities of empirical data over several years because there are multiple factors responsible for high temporal variation in mushroom productions. These include variations in precipitation, temperature, frost, evapotranspiration, relative humidity, and water deficits (Mártinez de Aragón et al. 2007, O'Dell et al. 1999; Ohenoja 1993; Straatsma et al. 2001; Wilkins and Harris 1946).

This paper presents empirical models for predicting the production of wild mushrooms in Scots pine (*Pinus sylvestris* L.) forests in the Central Pyrenees based on mushroom production data from three consecutive years. A mixed model technique was used to account for random annual variation of mushroom productions.

## 2. Material and methods

### 2.1 Mushroom plots

In 1995, 36 plots of 10 × 10 meters were established in *Pinus sylvestris* plantations of the Central Pyrenees in order to evaluate the productivity and diversity of ectomycorrhizal and edible fungi in this forest community. These plots, randomly selected from a total of 118 plantations, ranged from 5 to 84 years in age. The plots represent different Scots pine stand conditions with respect to site and density (see Table 1), and management practices. The site index (dominant height at 100 years) ranged from 13 m to 27 m.

The plots were sampled at 1-week intervals from September through November during the 1995, 1996 and 1997 autumn seasons. The mushroom production data were obtained by species and are expressed as fresh weight per hectare. Table 1 shows two main groupings: all species and the marketed edible species. Additional information on the sampling sites, the fungal species list and inventory methodology can be found in Bonet et al. (2004).

**Table 1.** Summary of stand variables and mushroom productions for the 24 plots used for modelling the production of mushrooms. The stand variables are given for the first year of the mushroom production measurements (1995). The mushroom productions are the averages of the 3-year measurement period.

| Variable | Mean | Standard deviation | Minimum | Maximum |
|---|---|---|---|---|
| | | Stand variables | | |
| T (yr) | 27.9 | 12.4 | 10.4 | 55.3 |
| $H_{dom}$ (m) | 12.3 | 4.4 | 3.3 | 20.0 |
| G ($m^2$ $ha^{-1}$) | 20.6 | 13.6 | 1.0 | 54.8 |
| $N_{trees}$ (trees $ha^{-1}$) | 1171.7 | 392.3 | 717.2 | 2196.3 |
| $D_m$ (cm) | 17.2 | 7.0 | 4.9 | 34.2 |
| SI (m) | 22.3 | 2.9 | 13.3 | 27.5 |
| Elevation (m) | 1238.8 | 220.2 | 846.0 | 1528.0 |
| Aspect (degrees) | 179.9 | 130.4 | 4.0 | 356.0 |
| Slope (%) | 24.1 | 7.2 | 7.0 | 38.0 |
| | | Mushroom productions | | |
| Total (kg $ha^{-1}$) | 123.7 | 135.2 | 0.2 | 466.6 |
| Marketed (kg $ha^{-1}$) | 25.6 | 39.1 | 0.2 | 153.4 |

[a] T: stand age; $H_{dom}$: dominant height; G: stand basal area; $N_{trees}$: the number of trees per hectare; $D_m$: mean diameter; SI: site index at a reference age of 100 years.

## 2.2 Forest plots

To determine mushroom productivity, 24 forest plots were established in 2006 within the mushroom plots to measure relevant site and growing stock variables. The other plots had either been cut or significantly transformed through management actions. The plot area varied between 0.04 and 0.16 hectares. Plots were established so that at least 100 trees with dbh> 7.5 cm were within the plot. For each plot, tree diameter at 1.3 meters height (dbh) and the growth for the last ten years were measured for all trees. In addition, tree heights, tree age and bark thicknesses were recorded from a sample of at least 20 trees per plot.

## 2.3 Methods

### 2.3.1 Modelling

The forest stand measurements taken in the winter 2006 correspond to the stand characteristics of these plots at the end of the 2005 tree-growing season. The mushroom production data were collected in the autumns of 1995, 1996 and 1997, also at the end of the tree-growing season (September through November). Before modelling mushroom productions based on forest stand characteristics (Table 1), stand measurements for 1995, 1996 and 1997 were back transformed from the conditions in 2006.

The predicted variable in the mushroom production model was the logarithmic transformation of the yearly production. The predictors were chosen from stand and site variables as well as their transformations. Due to the hierarchical structure of the data, mushroom measurements of the same year were correlated observations as were the measurements on the same plot, the generalised least squares (GLS) technique was applied to fit mixed linear models. The linear models were estimated using the maximum likelihood procedure of the computer software SPSS (SPSS Inc. 2005). The following random parameter model (also called mixed model) was the basic model:

$$y_{ij} = f(x_1, x_2, ..., x_n) + \mu_i + \mu_j + \varepsilon_{ij} \tag{1}$$

where $y_{ij}$ is the mushroom production of plot *i* n year *j, f*(.) is the fixed part of the model, $x_1$, ... $x_n$ are predictors, $\mu_i$ is random plot factor, $\mu_j$ is a random year factor and $\varepsilon_{ij}$ is residual (that part of the production which is not explained by the fixed part, plot factor and year factor). The model was fitted for the total production, production of edible species, production of marketed species, and productions on individual species or species groups.

## 3. Results

### 3.1 Models for mushroom production

The regression analyses showed that stand basal area, elevation, aspect and slope were the most significant predictors of mushroom productions. No other variables had a significant contribution to the fitting statistics after these variables had been included in the models. Therefore, the model set prepared to describe the dependence of mushroom productions on stand and site variables was as follows:

Total production
$\ln(y_{ij}) = 0.981 + 2.483\ln(G) - 0.128G + 0.934\cos(Asp) - 0.0135Slo^{1.5} + u_i + u_j + e_{ij}$ (2)

Marketed mushrooms
$\ln(y_{ij}) = -6.236 + 1.246\ln(G) - 0.0599G + 0.00459Alt + u_i + u_j + e_{ij}$ (3)

, where $y_{ij}$ is the production of plot *i* in year *j*, *G* is stand basal area ($m^2\ ha^{-1}$), *Asp* is aspect (rad), *Slo* is slope (%, i.e. 45 degrees is equal to 100%), *Alt* is elevation (m above see level), $u_i$ is random plot factor, $u_j$ is random year factor, and $e_{ij}$ is residual. All random factors ($u_i$, $u_j$ and $e_{ij}$) are assumed to be normally distributed with mean equal to zero. The variances of the random factors are given in Table 2 together with some fitting statistics.

All the regression coefficients of predictors were significant ($p < 0.05$).

When only the fixed part of the model is used for predicting (as is usual), the Snowdon correction factor should be used (Snowdon 1991). The exponentiations of the predictions of the fixed model part should be multiplied by the Snowdon factors shown in Table 2 rather than adding $(u_i+u_j+e_{ij})/2$ to the logarithmic production.

Even though plot and year factors are rarely used in prediction, it is interesting to note that the year factors of 1995, 1996 and 1997 correlate with the September–October rainfall of those years (Table 3). This suggests that the year factor may be partly predicted from climatic data and in this way the mushroom production prediction of the current year could be improved (after knowing the amount of autumn rains). If the fixed model part predicts a total production of 100 kg, more accurate production predictions for 1995, 1996 and 1997 would be as follows:

- 1995: Production = exp(ln(100)+0.0063) = 101 kg $ha^{-1}$
- 1996: Production = exp(ln(100)+0.5644) = 176 kg $ha^{-1}$
- 1997: Production = exp(ln(100)-0.5707) = 57 kg $ha^{-1}$

These calibrated predictions vary in the same way as the measured mean productions, which were 118, 177 and 77 kg $ha^{-1}$, respectively, in 1995, 1996 and 1997.

**Table 2.** Variances of random factors, fitting statistics and the Snowdon correction factor for the mushroom production models. Low values of residual variance, -2 × Log likelihood and Akaike's information index (AIC) imply good fit.

| | Total production | Marketed mushrooms |
|---|---|---|
| Variance of | | |
| • plot factor (uj) | 0.216 | 1.929 |
| • year factor (uj) | 0.353 | 0.854 |
| • residual (eij) | 0.805 | 1.105 |
| Total variance | 1.374 | 3.888 |
| -2 × Log likelihood | 223.6 | 294.0 |
| AIC | 229.6 | 300.0 |
| Snowdon correction | 1.511 | 3.011 |

**Table 3.** Year factors of the model for total mushroom production (Equation 2) and rainfall for September–November in the Central Pyrenees

| Year | Year factor | Rainfall (mm) |
|---|---|---|
| 1995 | 0.0063 | 60.0 |
| 1996 | 0.5644 | 72.6 |
| 1997 | -0.5707 | 33.2 |

According to the models, mushroom productions are the highest when stand basal area is 10 – 20 $m^2$ $ha^{-1}$ (Fig. 1). Aspect is another factor which strongly affects the predicted production so that northern aspects have the highest productions and southern the lowest. Aspect has a similar effect also on the production of marketed mushroom (Equation 3) but in this model the effect of aspect was not statistically significant.

Increasing altitude improves the total and marketed mushrooms production and increasing slopes decreases the total mushroom production. In fact, all the used predictors (basal area, altitude, aspect and slope) have a similar effect for the total and marketed production but not all predictors were statistically significant in both models. Figure 2 depicts the effects of stand basal area, slope and aspect on total mushroom production.

The predictions have a rather good correlation with the measured productions, especially when the plot and year factors are used in prediction (Fig. 3). Fig. 3 shows the mean productions of the 3-year measurement period indicating that the models predict the overall level of the mushroom production of Scots pine dominated stands in Central Pyrenees fairly well.

## 4. Discussion

Mushroom pickers typically look for precise weather forecasts to predict when and where to search for wild mushrooms each year. However, for forest managers, who are interested in maximising the production of this non-timber product, predictions must go beyond annual weather conditions to develop management programs that can enhance mushroom

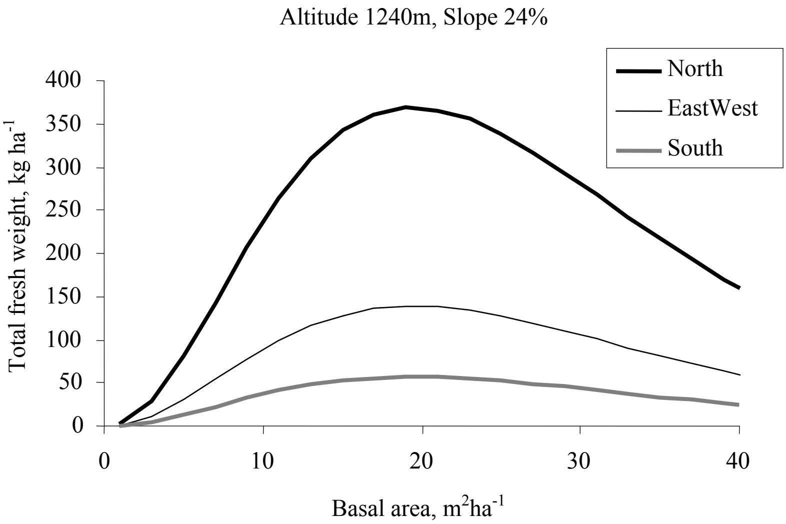


**Figure 1.** Mushroom production as a function of stand basal area and aspect according to Equation 2. Elevation and slope are equal to their mean values in the modelling data.

production. Of the traditional forest stand variables we found that stand basal area, elevation, aspect and steepness of slope were important predictors of mushroom productions.

Stand basal area is correlated with site conditions such as soil quality, water availability, temperature and overall forest health. It is logical that this variable can predict mushroom production given that carbon allocation to all ectomycorrhizal fungi is derived from the live standing biomass. Approximately 90% of fungi in the 3-yr inventory were fruitbodies of ectomycorrhizal species.

In this study, stand basal area was correlated with several other stand variables including site index, stand age, growing stock volume, and tree size. Estimation of the effects of other variables would require more plot measurements or a population in which stand variables are less correlated.

An important observation is that the highest mushroom production coincides with the stage of stand development where forest volume growth is the highest. This supports the study from Nara et al. (2003) which demonstrated that formation of mycorrhizal sporocarps was correlated with the growth and photosynthetic rate of the host trees.

The lower mushroom production observed at lower stand basal area could be a reflection of the lower forest stand photosynthesis with less carbon available for belowground allotments. These sites are usually warmer and dryer. In contrast, in our overstocked forests with high basal areas, mushroom production, as well as photosynthesis, may be limited by decreased water availability to support the high leaf area. In these stagnated stands, photosynthates are directed at maintenance rather than belowground assimilation and respiration.

Elevation, aspect and slope, in the Prepyrenees range, also reflect water availability, and soil quality. Elevations ranged from 900-1500, and forests located near 1200 m typically have higher rainfall and cooler temperatures than at 900 m. At the very highest elevations, temperatures may be too low for abundant mushroom production. Northern-facing slopes are characteristically more shaded and protected from the intense afternoon solar exposure

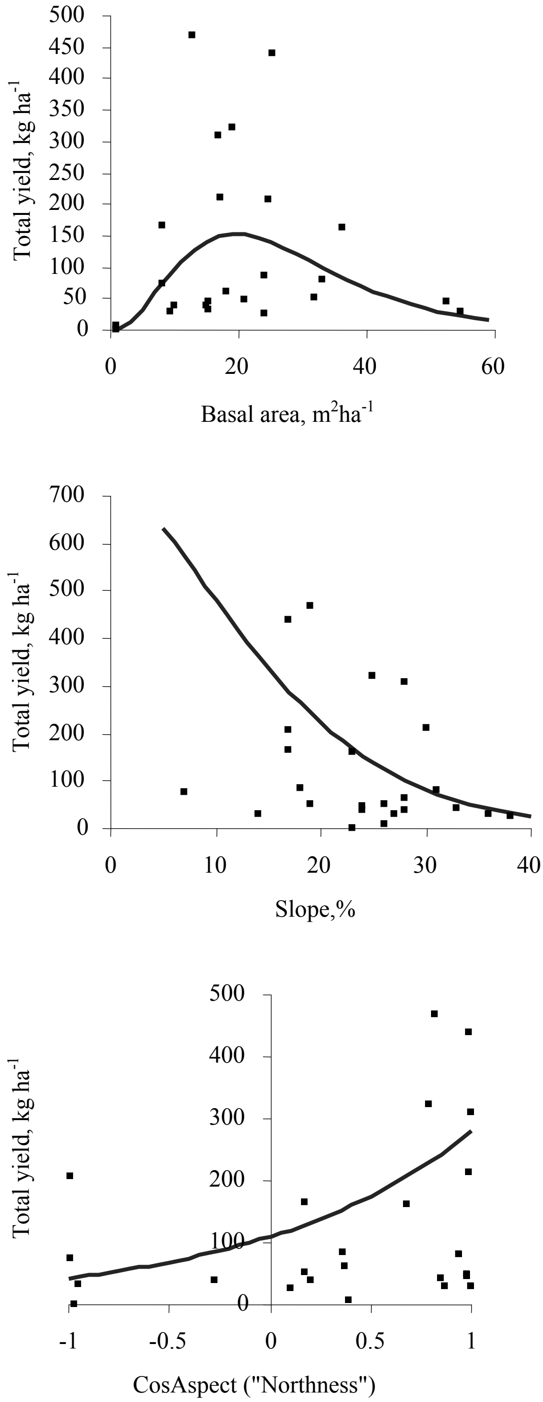


**Figure 2.** Dependence of total mushroom production (kg $ha^{-1}$) on stand basal area, slope and aspect. The dots indicate the means of the measured productions of the plots (3-year averages) and the curves are predictions of Equation 2.

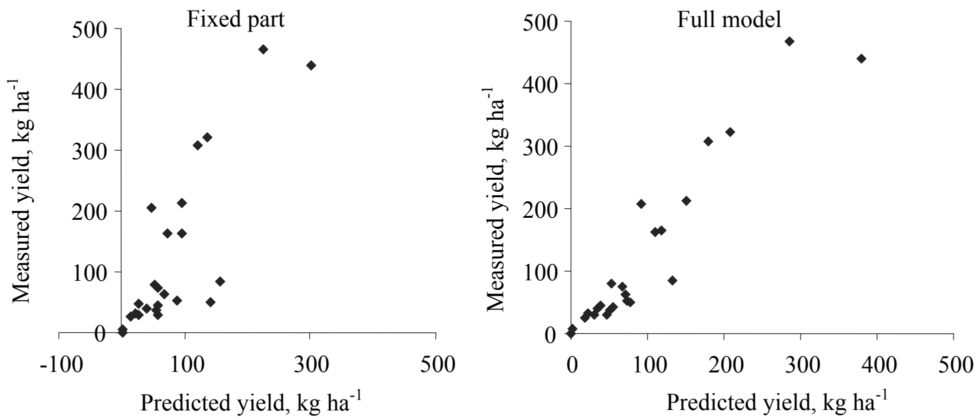


**Figure 3.** Correlation between predicted (Equation 2) and measured mean annual production of mushrooms calculated with the fixed part on the model (left) or by using the plot and year factors in prediction (right).

that south-facing slopes experience in late summer and early autumn months. Increasing slope has been shown to have a negative impact on mushroom production, most likely due to increasingly thinner soils associated with steep grades and greater water runoff than in forests with a less steep gradient.

The results of this study are encouraging because they demonstrate that mushroom productions are related to stand characteristics that can be influenced by silvicultural interventions. However, a larger data set would also make it possible to model the dependence of mushroom production on stand variables other than basal area, for instance stand age, species composition, and vertical structure of the canopy. Currently, a new set of mushroom plots is being inventoried in order to expand the data set to other tree species and stand conditions.

A future research need is to evaluate the effects of silvicultural interventions on mushroom productions. In this context, Pilz et al. (2006) found that forest thinning significantly reduced fruitbody production of the economically important ectomycorrhizal fungus, chanterelle (*Cantharellus formosus*), in the first year after light and heavy thinning treatments, but that these differences disappeared within 2–6 years. Reduction of basal area in our overstocked forests could potentially result in decreased mushroom production immediately after thinning, with a potential for increased fruitbody production when tree density matches levels that promote vigorous growth.

## Acknowledgements

This study has been funded by the research project AGL2004-00382 (Ministerio de Educación y Ciencia of Spain, Secretaria de Política Científica y Tecnológica) and by the Departament de Medi Ambient i Habitatge of the Generalitat de Catalunya. We are also grateful to the inventory group of the Forest Technology Centre of Catalonia for valuable assistance in the characterization of forest plots. We thank the anonymous reviewers for their helpful comments.

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# Evaluation of Cork Production in Kroumirie Cork Oak Forest, Tunisia

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## Abstract

Cork production weight and volume were measured within one harvesting period (12 years) in six plots representing variable damage stages of *Cytisus* sp cork oak overstorey in the Kroumirie forest area. Eight trees were sampled in these plots to evaluate the cork production. The results were used to estimate the whole Khroumirie cork oak forest. Those values were compared to those of the national forest inventory and of the real cork weight extracted by the Forest Harvesting Administration (Regie d'exploitation forestiere). The experimental values showed large variabilities between the best site (3985 kg dry weight $ha^{-1}$ $period^{-1}$) and the worst site (15 kg dry weight $ha^{-1}$ $period^{-1}$). The cork volume estimated by the regression line showed a value 8% lower than that of the national inventory data (45 851 vs 42 126 $m^3$ $year^{-1}$). However, the cork biomass extracted by the forest harvesting administration was 11.2% lower than that of value estimated by this study (9773 vs 11 002 tons $year^{-1}$). The cork oak productivity in cork was divided into homogeneous production classes. The results showed that in 14.5% of the whole cork oak forest area harvest was more than 1500 kg dry weight $ha^{-1}.period^{-1}$ while 56% is between 1500 and 500 kg dry weight $ha^{-1}$ $period^{-1}$. The lowest biomass potential values were produced in 29.5% of the whole Kroumirie cork oak forest area (less than 500 kg dry weight $year^{-1}$ $period^{-1}$).

*Keywords: cork; cork oak; cork production; Kroumirie; Tunisia*

## 1. Introduction

Cork production has high economic and ecological importance. In the southern Mediterranean area it is also of social basis. World cork production has shown continuous regression during

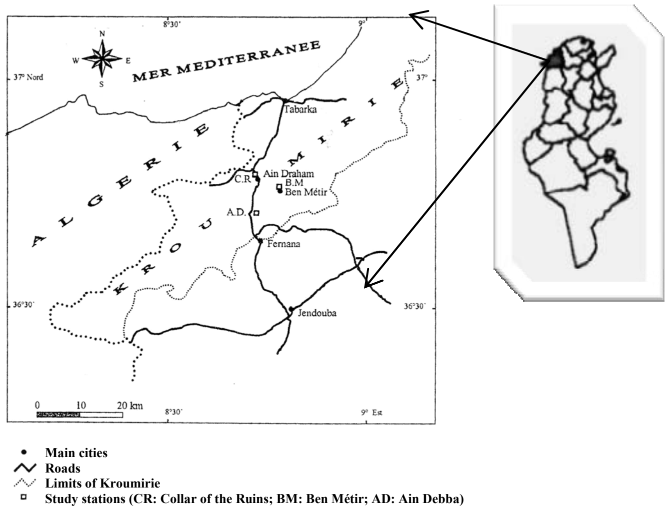


**Figure 1.** Experimental stations in Kroumirie cork oak forests.
(CR: Collar of the Ruins; BM: Ben Métir; AD: Ain Debba) (Sebei et al, 2001).

the last decades. This decline is due particularly to increasing mortality rates caused by insect and fungi attacks (Ben-Jamaa et al. 1992; Et Tobi 1996). This trend is also aggravated by climatic changes, mainly droughts (Rognon 1997).

The anthropozoic action and the significant reduction in the area have also accentuated the regression of the Tunisian cork oak forest area. Indeed, the clearing, overgrazing and illegal cuttings are other factors also contributing to the degradation and regressive dynamics of the oak forests and therefore to a decline of cork production in cork oak areas (Saoudi 1983; El Hamrouni 1992).

Some research results in Tunisia have evaluated the biomass of cork oak trees and under-covered vegetation as well as the productivity of cork oak (Sebei et al. 2001 and 2004). Other studies have estimated the volume of cork production in Kroumirie (I.F.N. 1995 and 2005).

The objective of this work is to evaluate and compare the cork yield to the values of the national forest inventory and the data measured by the forest harvesting administration.

The cork produced was estimated based on eight trees in a rotation period (12 years). Allometric relations were determined in order to evaluate the production within a rotation in the different experimental plots. Productivity results were used to establish cork production classes based on damaging sequence of *Cytisus* cork oak forests per rotation and hectare. Based on the findings of the experiment we were able to estimate the proportion of the relative area to different degradation stages of Kroumirie cork oak forest.

## 2. Material and methods

The present study relates to six areas of one hectare each, at the end of the rotation and localised in three stations in the suberaie (*Quercus suber*) with laburnum (*Cytisus villosus*) of Kroumirie, in the North-West of Tunisia. They are located at the Collar of the Ruins (CR), Ben Métir (BM) and Ain Debba (AD) (Figure 1).

In each station, two plots were selected depending on the state of the raised and shrubby layers.

- Preserved plot (noted 1)
- Damaged plot (noted 2)

The localization of the stations and the climatic, edaphic and syntaxinomic characteristics of the plots were described by Sebei et al. (2001).

From eight trees samples at the end of the rotation, we measured the height (*H*) of stripping of cork, the DBH under cork and the thicknesses of cork at the base and the height of stripping of cork (*eb* and *eh*), respectively, of each tree.

The volume of cork of reproduction per tree was calculated by applying the formula:

$$V1 = \pi.h.DBH.\frac{eb+eh}{2} \tag{1}$$

DBH, $e_b$ and $e_h$ are respectively diameter at breast height; the thickness of cork at basal area and at the height of cork stripping of the tree

The biomass of the cork of reproduction of each tree was given using the following relation:

$$b = V1 * d \tag{2}$$

*d* is the density of air dried cork

Annual production out of cork of reproduction $\frac{\Delta b}{\Delta t}$ for each tree sample was obtained by dividing the biomass (*b*) by the period of a rotation (12 years)

This annual production per tree was correlated with the DBH under cork and this relation was applied to *DBH* classes in order to calculate the exploitable cork productivity according to the formula:

$$\frac{\Delta B}{\Delta t} = \sum_{i=1}^{q} ni \frac{\Delta bi}{\Delta t} \tag{3}$$

Where $\frac{\Delta bi}{\Delta t}$ is the productivity of the tree means of class *i*, while $n_i$ is the number of trees in the class *i*. For each class of DBH, $\frac{\Delta bi}{\Delta t}$ was deduced from its mean DBH ($D_i$) class using the relation between $\frac{\Delta b}{\Delta t}$ and the DBH.

The density of cork on the stump was measured using a mercury voluminometer (standard Amisler 9/573) out of 13 samples taken out of seven trees of various diameters.

The density of the air dried cork was measured in a cork storage area. The cork (21 samples) was taken from the storage stack at various heights and exposures.

A correlation between the basal area and the production of exploitable cork was given in the study plots. Indeed, this dendrometric parameter (basal area) showed as being the best explanatory variable of the biomass (Sebei et al. 2001) and of the primary productivity (Sebei et al. 2004) on the level of a tree.

The estimation of the production of exploitable cork on trees with girth with cork at breast height (C1.30) higher or equal to 70 cm (Motte, 1960) (DBH of 22.28 cm) limit applied in the extraction of cork in the Tunisian cork oak population (Forest Harvesting Administration) (Figure 2).

Based on the work of Sebei et al. (2001) the measurements were made on 6 plots (1 ha for each plot) according to the histogram distribution of the trees related to the DBH classes below cork (Figure 3).

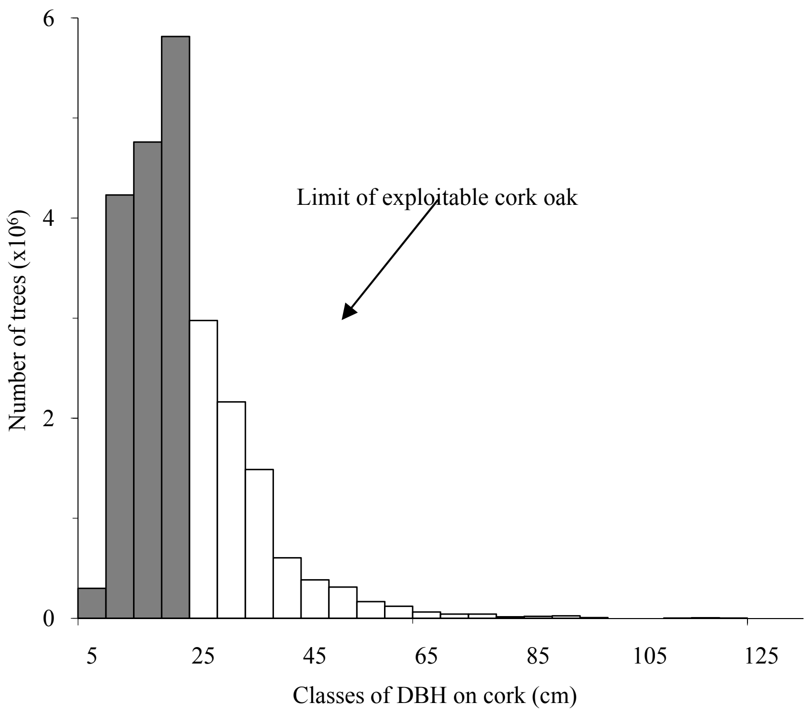


**Figure 2.** Number of cork oak trees related to the DBH on cork in Kroumirie forest (IFN 1995).

The estimation of extractable cork production in studied plots was evaluated on trees with DBH greater than 17 cm (below cork) (Sebei et al. 2001).

Mathematical relationships between cork biomasses and DBH, exploitable cork and Basal area parameters were performed using Microsoft® Excel 2000® software. The best fit was selected by considering the correlation coefficient (Dagnelie 1975).

## 3. Results and discussion

The exploitable cork **Y** (kg.tree$^{-1}$) is in a power relation to the DBH **X** (cm) of the trees below cork

**Y** = 0.0123 **X** 1.6843 r=0.987*** (n=8) (4)

This equation was applied to exploitable cork oak trees for each plot of experimental stations in Figure 3, then we estimated extractible cork on trees (based on density of humid cork and air dried extractible cork (Table 1)

Figure 4 shows the relationship between the basal area (X in m$^2$.ha$^{-1}$) and the production of cork on tree or air dried (Y in t.ha$^{-1}$.yr$^{-1}$). The regression equations are linear with high correlation coefficient.

The regression equations (5) and (6) estimate the total cork productivity on tree and air dried cork. They are based on total basal areas of the various classes of DBH cited in the

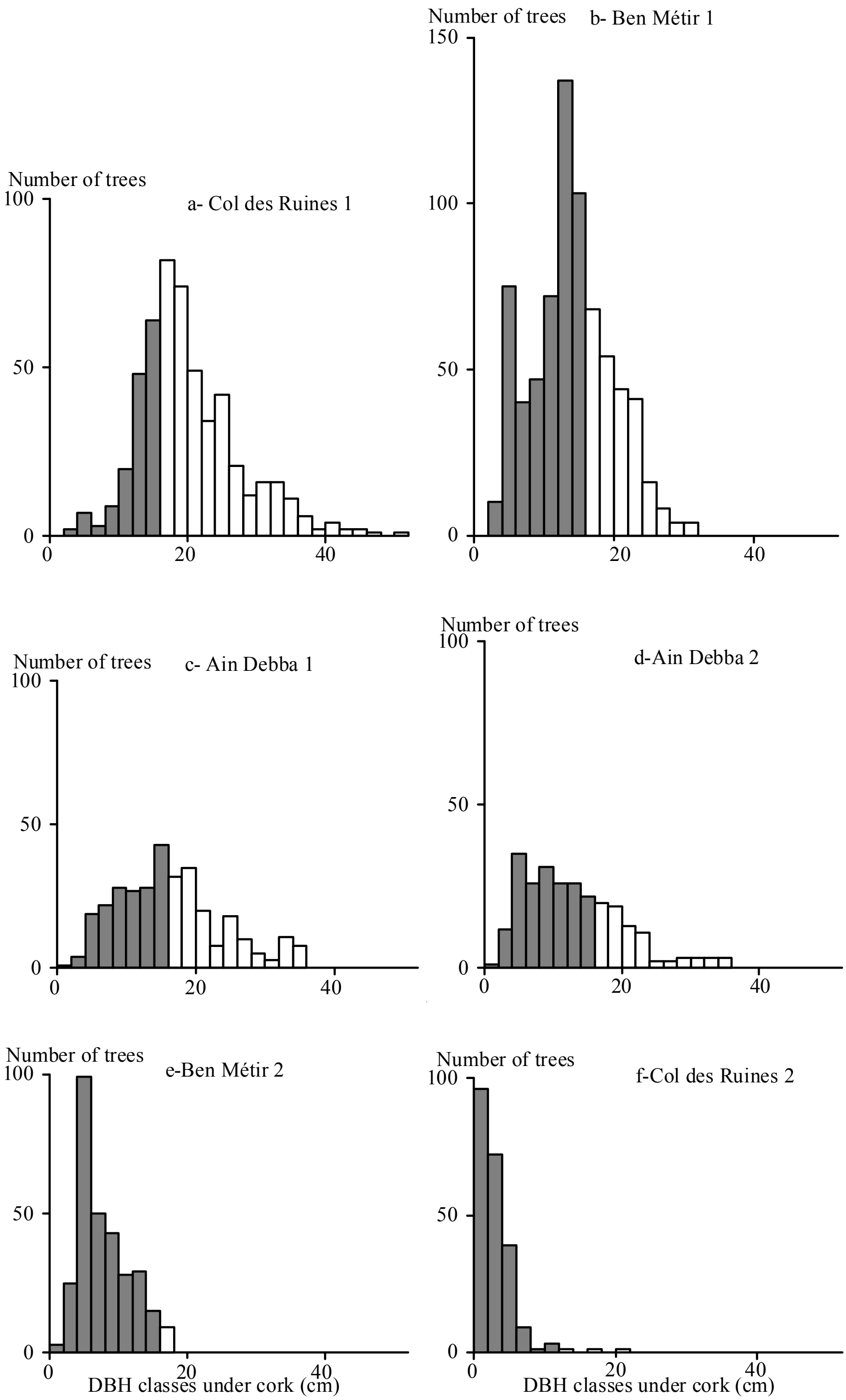


**Figure 3.** Distribution of trees related to DBH in 6 plots (1 ha each) representing variable damage stages of cytisus cork oak forest in Kroumirie region (Sebei et al. 2001)

**Table 1.** characteristics of the cork oak population and the cork production on trees and air dried cork.

| Plots | Number of trees per hectare | | | G | EC on tree[1] | EC air dried[2] |
|---|---|---|---|---|---|---|
| | Extractible cork oak | Non extractible cork oak | Total | m².ha-1 | Kg/ha-1 | |
| CR1 | 354 | 174 | 528 | 26.59 | 6992 | 3973 |
| BM1 | 239 | 484 | 723 | 13.82 | 3649 | 2075 |
| AD1 | 150 | 172 | 322 | 10.35 | 2695 | 1533 |
| AD2 | 79 | 179 | 258 | 5.01 | 1322 | 752 |
| BM2 | 9 | 292 | 301 | 0.38 | 103 | 59 |
| CR2 | 2 | 221 | 223 | 0.11 | 27 | 15 |

G: basal area of extractible cork oak trees per rotation, EC: Extractible cork, 1: density of cork on tree = 0.422 ± 0.102, 2: density of air dried cork = 0.240 ± 0.068 CR: Collar of Ruins; BM: Ben Métir; AD: Ain Debba

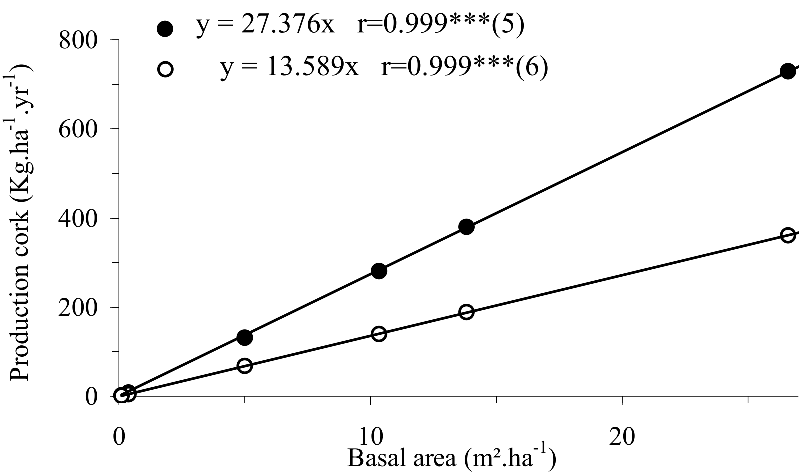


**Figure 4.** Relations between basal area and cork productivity in cork on tree (•) or air dried cork (o) in 6 plots (1 ha each) representing variable.

Figure 2. The coefficient 27.376 of the equation (5) is lower than that of Montero et al. (1991) (36.128) in Spain. The cork in Spain is more humid before extraction (42% in Tunisia and 49% in Spain).

The estimated cork production by the regression was compared to the values published by the National Forest Inventory (IFN). (1995) and with cork harvests carried out by the R.E.F. between 1986 and 2000 (Table 2). The productions in volume in this work were obtained by dividing the biomasses by the density of cork on tree.

Table 3 and Figure 5 illustrate the estimated cork production (kg.ha$^{-1}$.rotation$^{-1}$) in the total forest area (101.011 ha) in Kroumirie (Tunisia) (REF). The results showed that 14.5% of the whole cork oak forest area yields more than 1500 kg dry weight ha$^{-1}$.period$^{-1}$ while 56% is between 1500 and 500 kg dry weight.ha$^{-1}$.period$^{-1}$. The lowest biomass potential values were produced in 29.5% of the whole Kroumirie cork oak forest area (less than 500 kg dry weight ha$^{-1}$.period$^{-1}$).

**Table 2.** Comparison of the results of the IFN (*) and REF (**) of cork extracted in a rotation and those estimated in this work.

| Source | I F N* | R E F** | Present work |
|---|---|---|---|
| Cork on trees ($m^3.yr^{-1}$) | 42 126 | - | 45 851 |
| Cork on trees ($t.yr^{-1}$) | - | - | 22 192 |
| Air dried cork ($t.yr^{-1}$) | - | | |
| Live trees | | 8169 | 11 002 |
| Dead trees | | 1604 | |

*: National Forest Inventory (IFN)
**: cork extracted from1986 to 2000 by the Forest Harvesting Administration (REF)

**Table 3.** The estimated cork production ($kg.ha^{-1}.rotation^{-1}$) in a rotation and in a cork oak forest area 101 011 ha in Tunisia (according to the data of the REF); those limits of production cork were determined in the study plots.

| Classes of exploitable cork ($kg.ha^{-1}.rotation^{-1}$) (REF) | Area of Kroumirie cork oak forest (%) | Exploitable cork ($kg.ha^{-1}.rotation^{-1}$) | Cumulated cork oak forest area (%) |
|---|---|---|---|
| 3500–4000 | 0.61 | More than 3500 | 0.61 |
| 3000–3500 | 0.76 | More than 2000 | 6.34 |
| 2500–3000 | 2.07 | More than 1500 | 14.33 |
| 2000–2500 | 2.90 | More than 500 | 70.22 |
| 1500–2000 | 7.99 | Less than 500 | 29.78 |
| 1000–1500 | 18.50 | | |
| 500–1000 | 37.38 | | |
| 0–500 | 29.78 | | |

## 4. Conclusion

Our results showed that the amount of cork estimated in this work were closer to those evaluated by the National Forest Inventory; however the real quantity of the cork measured by The Forest Harvesting Administration (REF) showed lower values (11%). This over estimation may be due either to an error of estimation or to the quantity of the residues not measured by the REF.

Previous data showed that 14% of the cork oak forest produced the highest amount of cork (higher than 1500 kg $ha^{-1}$ $rotation^{-1}$) while the area (29%) producing the lowest quantity of cork within a period was less than 500 kg $ha^{-1}$ $rotation^{-1}$. These results showed that the cork produced by Kroumirie forest was decreasing because of the forest degradation; thus we recommend reviewing the process of the management in an integrated manner (antropozoic and natural factors). More research and modeling work should be done for more precise estimation especially as the strategy of the REF is to sell the cork on standing trees.

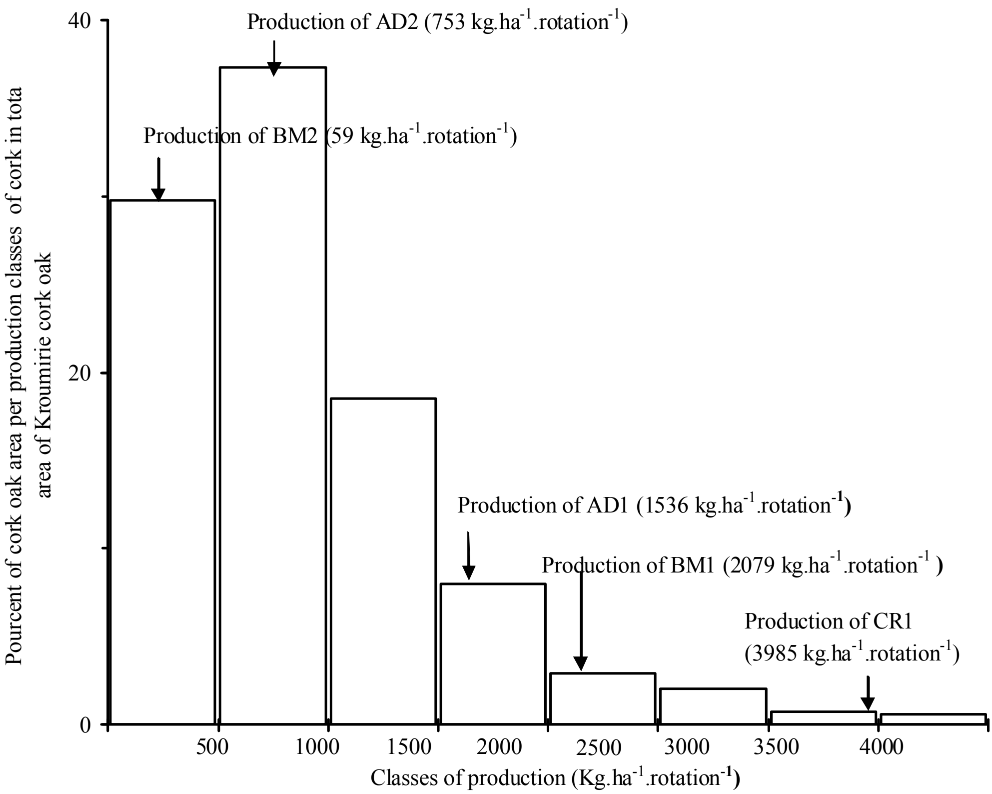


**Figure 5.** The estimated cork production (kg.ha$^{-1}$.rotation$^{-1}$) in a rotation and in a cork oak forest area 101 011 ha in Tunisia (according to the data of the REF); the arrows show the estimated production in our experimental plots.

## Acknowledgements

This work was funded by the Agricultural Research and Higher Education Institute (IRESA) of the Tunisian Ministry of Agriculture and Hydraulic Resources as a research project in the field of forestry. We would like to thank the Tunisian Forest Harvesting Administration (REF) for they provided all the data needed to undertake this work. Our thanks go to the General Direction of Forestry (DGF) of the Tunisian Ministry of Agriculture and Hydraulic Resources.

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# Scenario Analysis Applied to Cork and Holm Oak Forest Ecosystems in Southern Portugal

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## Abstract

Cork oak (*Quercus suber* L.) and holm oak (*Quercus rotundifolia*) ecosystems are characteristic of Mediterranean forestry in Portugal, and its main product, cork, is one of the most valuable products in the Portuguese forest sector. This paper focuses on techniques for oak ecosystems' scenario analysis. Both the linear programming model and the decision support system (DSS) architecture are addressed. The mathematical model includes objectives such as net present value, cork and timber flows and carbon stocks. The DSS – MfLOR - encompasses a modular structure, comprising a database system (INfLOR2.1), a prescription writer, a scenario analysis module and a graphical user interface. Results are discussed for a large-scale application encompassing over 1 million ha of cork and holm oak forest ecosystems in Southern Portugal. This approach demonstrates the usefulness and relevance of technological platforms for the effective integration of data, information and models, providing simulations and outputs that decision makers can use to guide their decisions.

*Keywords: Scenario analysis: forest management planning; cork oak forest ecosystems*

## 1. Introduction

Mediterranean ecosystem management encompasses multiple economic, social and ecological objectives. Addressing sustainability concerns in Mediterranean forest ecosystems management is thus a complex task that requires the integration of diverse data, information, models and methods. Ribeiro et al. (2004) addressed data quality issues pertinent to that integration. Further, the volume of growth and yield information for Mediterranean forest ecosystems has increased substantially in recent years (e.g. Tomé et al. 1999; Costa et al.

2003; Palahí et al. 2003; Trasobares et al. 2004; Sanchez-Gonzalez et al. 2005; Bravo-Oviedo et al. 2006; Sanchez-Gonzalez et al. 2007).

The potential for development and application of quantitative approaches to Mediterranean forest ecosystem management has thus improved. The literature reports exact (e.g. Borges et al. 1997; Diaz-Balteiro and Romero 1998 and 2003; Palahí and Pukkala 2003; Bravo et al. 2008) and heuristic (e.g. Falcão and Borges 2005; Gonzalez et al. 2005) approaches to both represent and solve Mediterranean forest management planning problems. There is also some experience with the development and application of decision support systems for Mediterranean forest management (e.g. Borges et al. 2003; Palahí et al. 2004; Falcão and Borges 2005). Yet these systems have been developed mostly for research and demonstration purposes.

This work builds upon both cork oak (*Quercus suber* L.) and holm oak (*Quercus rotundifolia*) growth and yield research (e.g. Tomé et al. 1999) and upon academic-driven technological platforms (e. g. Borges et al. 2003; Falcão and Borges 2005) to develop the first forest decision support system – MfLOR - to be used by a Portuguese Ministry of Agriculture Regional Office (DRAPAL). Preliminary results of its application to oak forest ecosystems scenario analysis in Alentejo (circa $1 \times 10^6$ ha) in Southern Portugal are discussed. They demonstrate the potential of quantitative techniques and information systems to provide effective support for strategic Mediterranean forest ecosystem scenario analysis.

## 2. Materials and methods

### 2.1 Materials

For scenario analysis purposes, DRAPAL considered an area in Alentejo in Southern Portugal extending over $1 \times 10^6$ ha. Cover types in this area are dominated either by cork oak or holm oak. These species may occur in pure or mixed composition, and in even-aged or uneven aged stands. Spacing also varies. The scenario analysis area was inventoried and firstly classified into 23 373 land units according to criteria such as the dominant and the secondary forest species, density, age and spatial contiguity (Figure 1). As the latter was not relevant for DRAPAL scenario analysis objectives, these land units were aggregated into 84 strata according to the first three criteria.

Both cork and holm oak prescriptions encompass thinnings. In the case of cork oak, prescriptions also involve cork extraction. The first debarking cannot take place until the tree circumference at breast height reaches 70 cm. Thus cork oak debarking usually starts when the age is between 20 and 30 years. Current legislation further prescribes a minimum tree debarking cycle of 9 years. Thinnings occur in debarking years and recently debarked trees are removed. Trees may live up to about 150 years or more. Cork oak ecosystem management modeling is a particularly complex task, for both tree growth and cork production must be taken into account (Falcão and Borges 2005).

### 2.2 Methods

Former decision support systems (Borges et al. 2003; Falcão and Borges 2005) had to be adapted and extended so that new functionalities needed for oak scenario analysis might be included. This involved the conceptualization and implementation of a management information system that might store and organize data from 608 oak plots in the 84 strata in

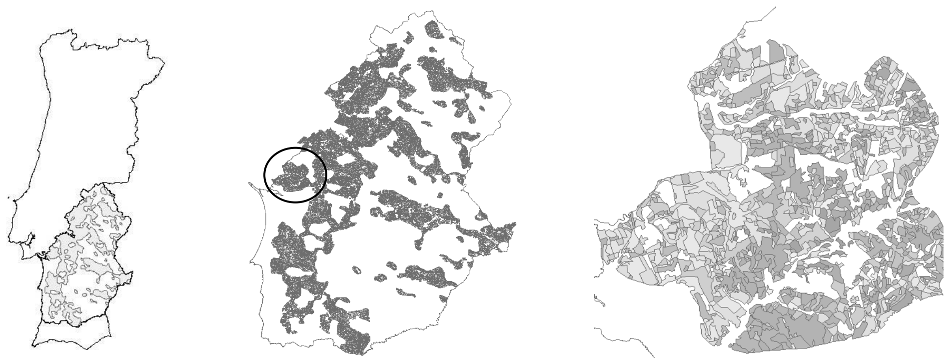

**Figure 1.** Scenario analysis area in Portugal and example of its spatial heterogeneity.

the scenario analysis area. The resulting MS Access 2003 relational database (INfLOR 2.1) encompassed 39 entities and stored data from 3764 cork oak and 1637 holm oak trees. The freeware MapWinGis stored the strata spatial data.

A simulator that might include the new cork and holm oak growth and yield models – SUBER v. 4.0 – was also developed. This model provides estimates of cork and timber yields. It further provides estimates of carbon stocks in the tree above the ground. The growth and yield models were encapsulated in a FORTRAN executable file that is called by the new simulator developed with the software Ms VB.NET. Combining the data stored in the database with the growth and yield models, the simulator plays a key role in the DSS, as it allows the automated generation for all strata of all strategies that are pertinent for scenario analysis. This information is outputted as a linear programming matrix for subsequent optimisation by a freeware linear programming solver GnuWIn32 that integrates MfLOR.

For preliminary scenario analysis purposes, a Model I type (Johnson and Scheurman 1977) linear programming model was developed:

$$\text{Max NPV} = \sum_{i=1}^{N} \sum_{j=1}^{M_i} c_{ij}\, x_{ij} \tag{1}$$

Subject to

$$\sum_{j=1}^{M_i} x_{ij} = A_i, i = 1, \ldots, N \tag{2}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{M_i} w_{ijt} x_{ij} = W_t \;, t = 1, \ldots, T \tag{3}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{M_i} cork_{ijt} x_{ij} = Cork_t \;, t = 1, \ldots, T \tag{4}$$

$$\sum_{i=1}^{N} \sum_{j=1}^{M_i} Carb_{ijt} x_{ij} = Carb_t \;, t = 1, \ldots, T \tag{5}$$

$$W_{t+1} \geq W_t, t = 1, \ldots, T-1 \tag{6}$$

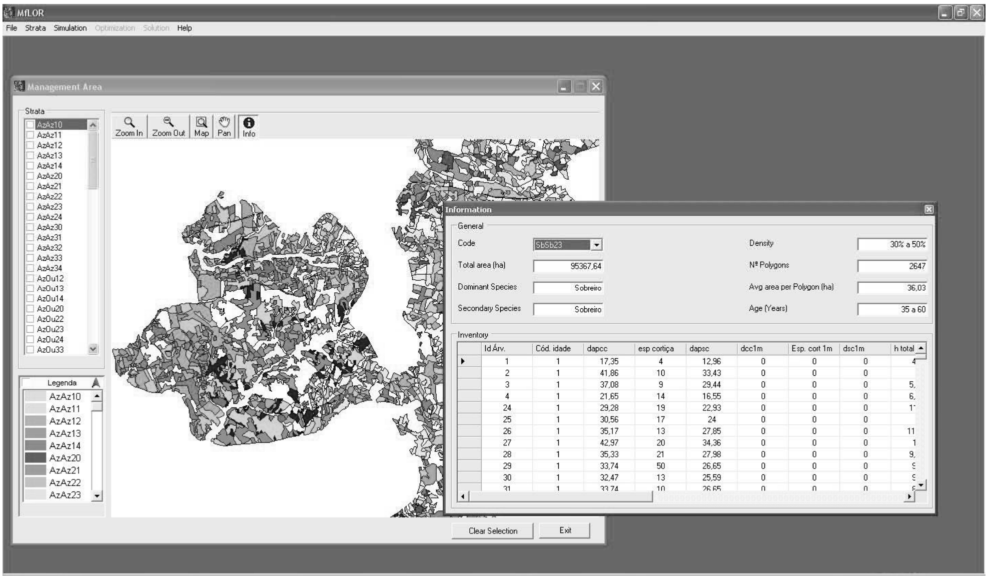


**Figure 2.** Form to access alphanumeric and geographical data from the scenario analysis area.

$$Cork_{t+1} \geq Cork_t, t = 1,\ldots,T-1 \tag{7}$$

$$Carb_{t+1} \geq Carb_t, t = 1,\ldots,T-1 \tag{8}$$

$$x_{ij} \geq 0, \forall i, j \tag{9}$$

where,

N = the number of strata (84).
Mi= the number of silviculture strategies for strata i.
T = the number of planning periods (5)
$x_{ij}$ = number of ha of strata i assigned to silviculture strategy j.
$c_{ij}$ = net present value associated with silviculture strategy j in strata i.
$W_{ijt}$ = wood flow in period t that results from assigning silviculture strategy j to strata i.
$Cork_{ijt}$ = cork flow in period t that results from assigning silviculture strategy j to strata i.
$Carb_{ijt}$ = average yearly carbon stock in period t that results from assigning silviculture strategy j to strata i.

Equation (1) defines the objective of maximizing net present income. Equation (2) states that the area assigned to each silviculture strategy can not exceed the strata area. Equations (3), (4) and (5) define the wood and cork yields and the average carbon stocks per product and planning period. Equations (6), (7) and (8) define the objectives of non-declining cork and wood flows and carbon stocks. Finally, equation (9) states the non-negativity constraints.

Graphical user interfaces were programmed so that the user may check strata-related information (Figure 2) and define parameters e.g. thinning intensities and cork extraction periods to simulate silviculture strategies in all strata (Figure 3). Typically, most important

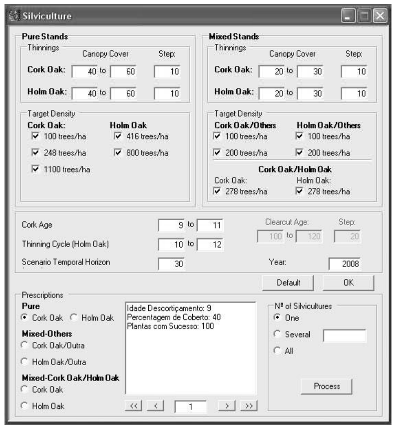


**Figure 3.** Form to define silviculture strategies.

silvicultural options encompass regeneration, thinnings and cork extractions. Most stands are uneven-aged and have densities of 70 to 150 trees per ha when mature. The first cork extraction cannot take place until the tree circumference at breast height reaches 70 cm. Thus cork extraction usually starts at the age of 30 years. A cork extraction cycle encompasses at least 9 years. Thinnings occur in cork extraction years and remove recently debarked trees. Trees may live up to about 150 years or more (Falcão and Borges 2005).

## 3. Results

The integrated functionality of all MfLOR modules – management information system, simulator and optimizer – was used to check whether policies aiming at non-declining cork and wood flows and carbon stocks might be sustained. A planning horizon of 5 ten-year periods was considered. The system allows the user to specify the number of strategies that might be simulated for each strata (Figure 3). Four test simulations were completed considering 10, 20, 40 and 100 strategies. The optimizer used the corresponding linear programming matrices for scenario analysis purposes.

In all 4 runs, the number of cycles varied from 6 to 27. A cycle corresponds to a combination of silviculture parameters (Figure 3) that may change over the planning horizon in a given strata. For example, in the case of strata where the only forest species present is the cork oak, a cycle may encompass the combination of 3 target densities, 3 cork extraction periodicities and 3 thinning intervals: 27 cycles are possible. After defining cycles, the system read the strata inventory data and simulated up to 8400 silviculture strategies for all strata over the 50-years planning horizon. Computational costs were reasonable. The most costly run took about 17 minutes in a Intel Core Duo 2.66 MHz machine with 1 Gb of RAM.

Increased flexibility led to a 13% increase in total net present value. In all test runs, it was shown that non-declining cork and wood flows and carbon stocks might be sustained (Figures 4 to 6). Current inventory does not constrain these policies. Actually, if no targets are set for the first period flows and stock, non-declining goals are met just by maximizing net present

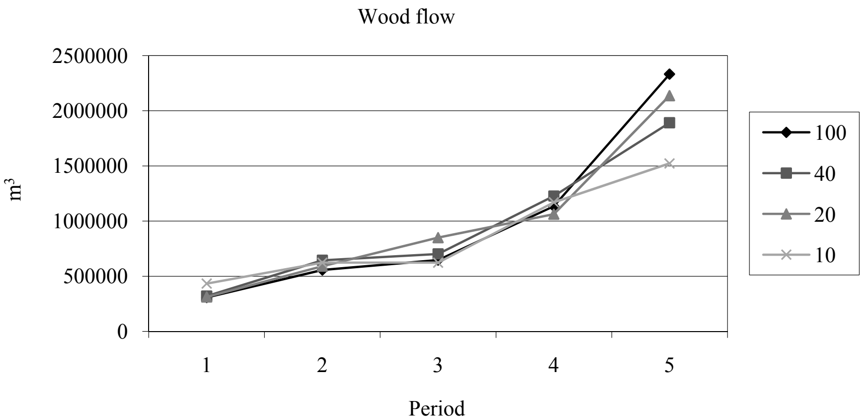


**Figure 4.** Wood flows in the 5 ten-year periods of the planning horizon in the case of the simulation of 10, 20, 40 and 100 strategies per strata.

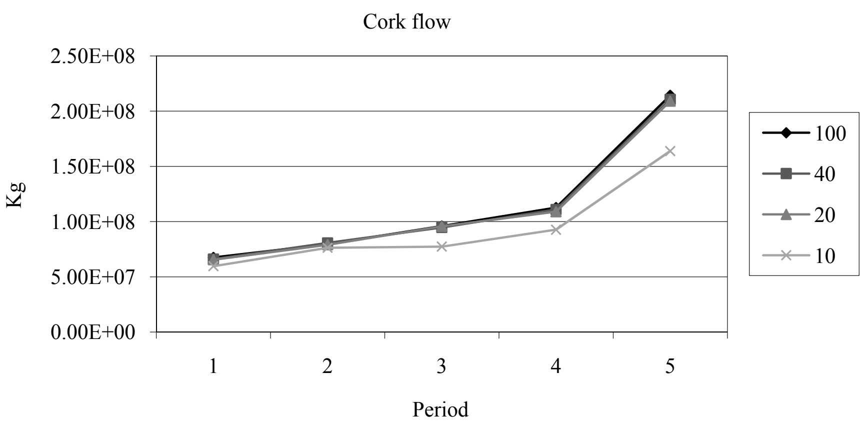


**Figure 5.** Cork flows in the 5 ten-year periods of the planning horizon in the case of the simulation of 10, 20, 40 and 100 strategies per strata

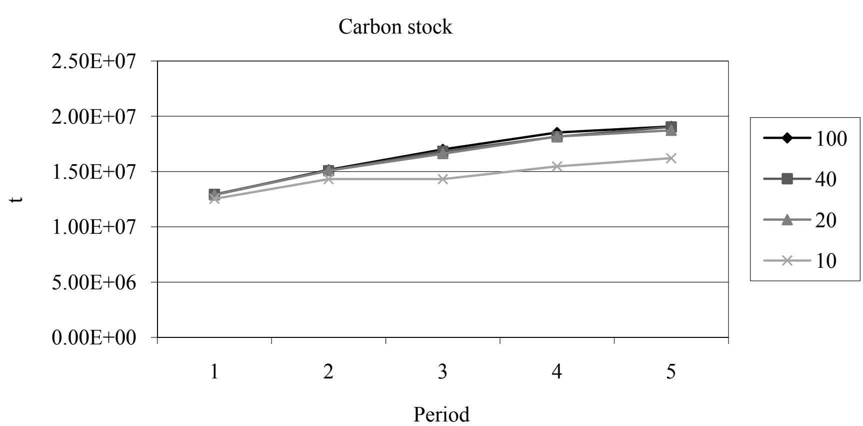


**Figure 6.** Carbon stock in trees and above the ground in the 5 ten-year periods of the planning horizon in the case of the simulation of 10, 20, 40 and 100 strategies per strata

value when 20, 40 and 100 strategies are simulated. Scenario analysis further shows that current inventory does not allow a cork flow of over $25 \times 10^6$ kg in the first planning period.

Dual values associated with area constraints also provide valuable information to assess the relative importance of each strata. As a consequence of the current linear programming formulation, generally cork oak strata are the most valuable. Cork revenues impact shadow prices substantially. Yet the higher value of holm oak timber as reflected in dual prices underlines the importance of this cover type.

## 4. Discussion

The current knowledge about Mediterranean forest ecosystem production functions provides opportunities for enhanced decision analysis. Quantitative techniques and traditional decision support systems become more useful for both management planning and regional scenario analysis. In the case of cork and holm oak forest ecosystems, existing growth and yield models provide information about cork and timber yields and carbon stocks in the trees and above the ground. This information was instrumental in developing a linear programming model and software to support cork and timber flows and cork stocks regional scenario analysis.

Preliminary results were presented to demonstrate the potential of the integrated functionality of the models and tools within the MfLOR system. The Portuguese Ministry of Agriculture Regional Office of Alentejo (DRAPAL) will start using this system in 2008 for scenario analysis. The possibility of adapting policy scenarios as the knowledge generated by the system increases is instrumental for sound policy making. Flexibility in linear programming matrix generation is key to this functionality. This system architecture may be further used for management planning.

Cork and holm oak forest ecosystems provide other goods and services (e.g. acorn production, livestock). The system is extensible as it allows for the updating and the insertion of production and conservation functions to address other objectives. A valuable functionality is the ability to provide multiple objectives tradeoff information.

## Acknowledgments

Partial support for this research was provided by Project INTERREG IIIA "Desarrollo de un sistema de información para la gestión ambiental y económica del ecosistema dehesa/montado en Extremadura y Alentejo. 2ª Fase" and by Project PTDC/AGR-CFL/64146/2006 "Decision support tools for integrating fire and forest management planning" funded by the Portuguese Science Foundation

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# Cultivation Methods of the Black Truffle, the Most Profitable Mediterranean Non-Wood Forest Product; A State of the Art Review

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## Abstract

The black truffle (*Tuber melanosporum Vittad.*) has become an important agricultural alternative in rural Mediterranean regions. The declines of wild production throughout its natural range, its high market value and the development of nursery and cultivation techniques have enhanced its successful cultivation during the last few decades. In this article, we present the state of the art of black truffle cultivation, the requirements of the fungi and the cultivation techniques of this culinary fungus.

*Keywords: Tuber melanosporum, cultivation techniques, land suitability*

## 1. Introduction

Cultivation of the black truffle (*Tuber melanosporum Vittad.*) can mean a vital source of prosperity for rural communities with suitable habitat, becoming a complementary activity to agricultural traditions, diversifying the rural economy and promoting a renewed land-use balance.

The historical evolution of the markets reveals a decrease in wild production and a rise in the demand for truffles over the last decades (Bonet and Colinas 2000). Due to its culinary standing – it is said that the black truffle is the "black diamond of the kitchen" – it has a high economic return as a specialty product making it attractive for cultivation and international marketing.

The black truffle has gained increasing interest as an agricultural alternative in marginal lands and depressed farming regions (Bencivenga et al. 1983; Romieu and Tabouret 1995).

This hypogeous ascomycete, which produces mature ascocarps or fruit bodies (truffles) in late autumn and winter, grows in ectomycorrhizal symbiosis with several tree species in Mediterranean conditions. It is native to the calcareous regions primarily of France, Italy and Spain and is found on well-drained, open forest or farmlands with high pH, warm summer temperatures and relatively low, but well-partitioned annual rainfall (Delmas and Poitou 1974).

Cultivation in orchards began intensively with the development of nursery techniques to induce *T. melanosporum* ectomycorrhiza formation in receptive host seedlings (Chevalier and Grente 1978). Productive truffle orchards in France, Italy and Spain presently provide rural landowners with an alternative to agricultural subsidies, promote restoration of abandoned cereal lands and require relatively low agricultural inputs (Samils et al. 2003).

Mass production of *Tuber*-colonized host seedlings has represented the most important progress in truffle cultivation for the past 30 years. In Spain the first plantations were established in the early seventies by importing plants from France, and at the onset of the eighties the first businesses to cultivate and sell locally grown plants began to appear. Since then, the expansion of truffle plantations has created an economic boom for the tree nursery-sector specializing in the production of truffle-inoculated seedlings.

Annual fresh weight productions from plantations vary with reports of 50 kg/ha from well-managed 13–14 yr-old plantations in Italy (Bencivenga and Di Massimo 2000), 45 kg/ha reported from irrigated plantations in Spain (Carbajo 2000) and 15–50 kg/ha with exceptional yields up to 110 kg/ha in 14 yr-old plantations in France (Chevalier and Frochot 1997). Average retail prices in Europe range from 300–450 euros/kg fresh weight (Olivier 2000) although summer droughts in the recent few years have contributed to low truffle productions and higher prices of up to 700–900 euros/kg for high quality truffles.

In many regions with suitable habitat, modern methods for truffle cultivation are not well known by local agriculturalists and experts, and there is limited information available for potential truffle growers. In this article, we provide a summary of the more solid recommendations published based on direct observations by the cited authors.

## 2. Land suitability

The most favorable land for the establishment of a truffle plantation is determined by its geographical, climatic, geological, soil, and biotic conditions.

### 2.1 Geographical Conditions

The geographical location may determine the distribution of truffles, but the geographical parameters themselves do not have much relevance and should be considered along with the climate.

#### Altitude

The appropriate altitude for the establishment of a plantation is a parameter presenting discrepancies among experts because it cannot be set apart from the latitude and orientation.

In Europe wild truffles are found from near sea level in France (Olivier et al. 1996) to 1800 m in Granada (Reyna 2000). In Spain the majority of wild truffle beds are located at around 600–1200 m.

### Aspect

The influence of orientation depends, in turn, on the altitude and latitude as well as exposure to dominant winds. The majority of wild truffle beds are found facing south, but when looking at the peninsular south, there is more of a tendency towards growth in the shade. For example, in Castellón there are more truffle beds facing south, while in Valencia the truffle beds prefer to face north. (Reyna 1992; 2000).

### Slope

Normally truffle beds are not found in completely level areas because of the risk of poor drainage (Reyna 1992). It is more frequent to find them on slight inclines (<15%) (Delmas and Poitou 1973; Reyna 1992; Hernández 1994), although wild truffle beds are quoted as having slopes of up to 60% (Hernández 1994).

## 2.2 Climatic Conditions

The climatic conditions that most influence production of the black truffle are precipitation and temperature.

### Precipitation

The availability of water is of great importance to truffle cultivation, above all during summer when precipitation has a decisive role in the growth of a truffle. Written works contain no experimental information on the combined water needs of the symbiotic organism and the host tree and the fungus. Available information refers only to precipitation. This information has important limitations, considering that a given precipitation which provides sufficient water needs for a plant grown in colder climates may create water stress for the same plant in warmer climates.

The suitable rainfall observed in wild truffle beds ranges between 425 and 1500 mm/year, with precipitation between 72 and 185 mm in summer months (Hernández 1994; Reyna 2000; Ricard 2003).

### Temperature

Truffles prefer Mediterranean climates with changing seasons and are capable of withstanding extreme conditions. Table 1 presents the ranges of optimum temperatures as described in written works. The ranges are based on observations from places where truffles grow but without experimental evidence that outside these places they cannot grow. For this reason, it is probable that some of these ranges will broaden as studies on truffle autecology advance.

Temperature limitations may be determined by the soil's suitability for a plantation. It is important to avoid extremes. For example, summer temperatures higher than 23°C for more than six days (Michels 2003) and winter temperatures lower than -10°C for more than five days (Olivier et al. 2002; Sourzat 2003) are excessive. Mulching can reduce the thermal amplitude, decreasing the soil temperature with a depth of 10 cm in the summer, while slightly increasing it in the winter (Michels 2003; Sourzat 2003).

**Table 1.** Proposed range of temperatures for cultivation of the black truffle (Reyna 1992; Hernández 1994; Callot and Jaillard 1996; Reyna 2000; García-Montero et al. 2001).

| | |
|---|---|
| Mean annual temperature (ºC) | 8.6 –14.8 |
| Mean highest temperature of the warmest month (ºC) | 23–32 |
| Monthly mean maximum temperature (ºC) | 17.4–23.5 |
| Mean lowest temperature of the coldest month (ºC) | (-2)–(-6) |
| Monthly mean minimum temperature (ºC) | 1 – 8.2 |
| Extreme maximum temperature (ºC) | 43 |
| Extreme minimum temperature (ºC) | (-9)–(-25) |

### 2.3 Geologic Conditions

The most preferred soil classifications are those from the Secondary-Mesozoic era including the Triassic, Jurassic and Cretaceous periods. Land with a soil classification from the late Jurassic period is best (Sáez and De Miguel 1995), although alluvial substratums from the Quaternary period are also suitable (Olivier et al. 2002).

### 2.4 Soil Conditions

Truffles develop on calcareous soils at a depth of 10-40 cm (Sourzat 1997) on Inceptisols, Entisols and Mollisols (Raglione et al. 2001).

The most appropriate soil parameters and approximate ranges for the correct location and development of a truffle plantation are as follows:

#### Stoniness

Soil stoniness is a positive condition for truffle production because it contributes to effective soil drainage and aeration. Surface stoniness lessens the amount of evaporation in the summer and protects the soil against compaction or erosion produced by rain. This creates a mulching effect as well as regulating the temperature of the topsoil (Callot 1999; Reyna 2000). Temperature moderation during hot periods helps to form condensation and insures soil fauna activity (Callot 1999).

#### Acidity or Alkalinity

The concentration of acidity or alkalinity in the soil is represented by the pH value. The pH value is one of the most important determining factors for truffle production due to its need for basic soils.

The recommended range for the cultivation of the black truffle lies between 7.5 and 8.5 (Delmas et al. 2001), the most favorable being around 8 (Poitou 1988; 1990). The pH of truffle beds varies between 7.1 and 8.85 (Bencivenga and Granetti 1988; Sáez and de Miguel 1995; Sourzat 2001).

### Calcium

Calcium carbonate is essential for the cultivation of the black truffle, although a low soil calcium level may be compensated for by a significant presence in the parent material or in large soil particles (Reyna 2000). If it is not present in large particles or stones, soil concentration must exceed 1% and may reach up to 83.7% (Bencivenga and Granetti 1988; Poitou 1988; Raglione et al. 2001).

### Texture

The most suitable soil texture for truffle bed establishment is a balanced loam. Excessively sandy soils are not acceptable because of their poor water retention capacity, and neither are heavy clay soils (with >46 %clay) (Raglione et al. 2001) because of elevated compaction. However, acceptable maximum levels of clay depend on stoniness, organic matter and the biological activity of the soil, all of which help aeration and prevent compaction.

Recommended soil textures for the cultivation of the black truffle are loam soils: sandy loam, clay loam, silty loam, sandy clay loam (Delmas and Poitou 1973; Grente and Delmas 1974; Reyna 2000), considering the texture classes of loam, sandy loam and sandy clay loam to be optimal (Colinas et al. 2007) although wild truffle beds are formed in almost every type of texture (Delmas et al. 1981; Bencivenga and Granetti 1988).

### Organic Matter

Organic matter in the soil improves structure, helps the formation of aggregates and increases porosity and cation exchange capacity. It also regulates the soil pH, increases water retention and stimulates biological activity. For these reasons it is an important factor to keep in mind when choosing the site for truffle cultivation.

The amount of organic matter in truffle bed soil varies considerably with minimum and maximum absolute values at 0.8% and 17.4% respectively (Delmas et al. 1981; Bencivenga and Granetti 1988). The recommended range for truffle cultivation is from 1.5% to 8% (Delmas and Poitou 1973; Grente and Delmas 1974; Poitou 1990).

### Macronutrients (N, P and K)

Despite being essential nutrients, significant concentrations of nitrogen, phosphorous and potassium in the soil are not necessary for truffle production. Generally, most soils have sufficient amounts of these nutrients for maintaining both fungal and tree growth and therefore, apart from unusual circumstances, there should not be deficiency problems. Usually problems associated with macronutrients are due to concentration levels having been raised too high from added fertilizer in cultivated fields. Plants depend on mycorrhizal fungi for capturing soil nutrients at the typically low concentrations found in most soils. When concentrations are exceptionally high, plants can absorb nutrients without the intermediary fungus and mycorrhizal colonization rates drop, which may cause the loss of the desired fungus (*T. melanosporum*, in this case), which depends on the tree for obtaining carbon (its energy source) and maintaining its life cycle.

The recommended range of organic nitrogen content (Kjeldahl) for the cultivation of the black truffle lies between 0.1% and 0.3% (Poitou 1987; Olivier et al. 1996; Sourzat 2001) with minimum and maximum absolute values from wild truffle beds at 0.05% and 0.52% (Delmas et al. 1981). Both the mycelium of the black truffle and soil microorganisms are capable of transforming the different forms of phosphorous into an assimilated form suitable for its host (Poitou 1987; 1988; Olivier et al. 1996; Sourzat 2001). In effect, the total measurement of phosphorous in truffle bed cultivation is more significant than the individual portions. The recommended range is from 0.1% to 0.3% (Poitou 1987; 1990; Olivier et al. 1996).

The recommended range for potassium content for cultivation of the black truffle lies between 0.01% and 0.03% (Poitou 1987; Olivier et al. 1996; Sourzat 2001) with minimum and maximum absolute values of natural truffle beds at 0.0096% and 0.12% (Delmas et al. 1981).

#### The C/N Relationship

The C/N relationship reflects the amount of mineralization in the soil and gives an indication of biological activity. This should be evaluated particularly in heavy soils with elevated clay content (Sourzat 2001).

The recommended range of the C/N relationship for cultivation of the black truffle lies between 8 and 15 (Delmas and Poitou 1973; Delmas et al. 1981; Poitou 1988; Sourzat 1997), with optimum values near 10 (Delmas and Poitou 1973; Poitou 1988; Sourzat 1997). The minimum and maximum absolute values observed in truffle beds are 0.1 and 26 respectively (Bencivenga and Granetti 1988; García-Montero et al. 2001).

#### Structure

The structure describes the way in which individual particles make up the soil and create resulting cavities. The best structure for the development of the black truffle is one which permits aeration within the soil and effective water drainage through the pores thus enabling penetration of the tree roots and the truffle mycelium (Delmas and Poitou 1973; 1974; Poitou 1988). The most ideal structure for black truffle cultivation is a granular or crumbly structure (Poitou 1988; Sourzat 1997).

Table 2 lists the recommended ranges for the main soil parameters.

### 2.5 Biological Conditions

#### Cultivation Land Use History

The legacy of previous crops where the plantation is established will affect the future evolution of the land. Cereals, forage crops, and leguminous plants are preferable crops (Reyna 2000). Vineyards and fruit orchards are also considered effective (Sourzat 1997) and in general, previous crops which form endomycorrhyzal symbiosis. In the case of woody crops, it is important to test the health of the roots. An infection caused by the pathogenic fungus Armillaria sp. could seriously affect the plantation. Other experts recommend a "biological cleaning" of the land by cultivating cereals or forage crops for at least one year (Verlhac et al. 1990) prior to truffle plantation establishment.

**Table 2.** Recommended range for the principle soil parameters for black truffle cultivation (Delmas and Poitou 1973; Grente and Delmas 1974; Delmas et al. 1981; Delmas et al. 1982; Poitou 1987; 1988; 1990; Bencivenga and Granetti 1988; Olivier et al. 1996; Sourzat 1997; 2001; Reyna 2000; Raglione et al. 2001).

| Parameter | Recommended range |
|---|---|
| pH | 7.5– 8.5 |
| Organic material (%) | 1.5–8 |
| Calcium carbonate (%) | 1–83.7 |
| Exchangeable Calcium (% calcium oxide) | 0.4–1.6 |
| Nitrogen (Kjeldahl) (%) | 0.1–0.3 |
| Phosphorus (%) | 0.1–0.3 |
| Potassium (%) | 0.01–0.03 |
| Texture | Loam, sandy loam, clay loam, silt loam, sandy clay loam |
| Structure | Granular or crumbly |
| C/N ratio | 8–15 |

### Host Trees

*T. melanosporum* can form mycorrhizas with evergreen holm oak (*Quercus ilex* sp. *ilex, Q. ilex* sp. *ballota*), semi-deciduous and deciduous oak trees, the "Quejigo" oak, and downy oak (*Q. faginea, Q. pubescens*), Kermes oak (*Q. coccifera*), hazelnut trees (*Corylus avellana*), rockrose (*Cistus incanus*), several pine species (*Pinus pinea, P. halepensis, P. nigra*), European hop hornbeam (*Ostrya carpinifolia*), European hornbeam or ironwood (*Carpinus betulus*), and linden trees (*Tilia* sp.) (Palenzona 1969; Manna 1992; Bencivenga et al. 1995).

### Plants Found Within the Physiologic "Burn"

There are a few plants which are not affected by the allelopathic properties of *T. melanosporum*, which is known to cause a "brule" or burn around the base of the host tree. Among them, Mahaleb cherry (*Prunus mahaleb*), dogwood (*Cornus sanguinea*), juniper (*Juniperus oxycedrus, J. communis*), stonecrop (*Sedum altissimum*) and red fescue (*Festuca rubra*) (Nicolas 1973; Sáez and De Miguel 1995; Olivier et al. 1996), and in areas with mild climates, *Ulex parviflorus* (Olivier et al. 1996; Sourzat 1997). However, Olivier et al. (1996) and Sourzat (1997) indicate that the dogwood is an unfavorable indicator species for land suitable for truffle production.

## 3. Planting

In order to begin planting it is necessary to prepare the land, obtain the plant, and to plant on the appropriate day, having already chosen the planting density.

## 3.1 Preparing the Land

Preparation of the land depends, in part, on previous land usage and the condition of the land at the time prior to planting.

In order to facilitate drainage and aeration, it is important to cultivate deeply with a subsoiler or a chisel in order to break up a possible hardpan from previous land use. Afterwards, superficial cultivation is important for smoothing and leveling the soil with graders or cultivators. The recommended time period is the summer and autumn months before planting. It should be done on dry ground and without mixing soil horizons.

Land cultivation can also to be carried out in sections of 1 meter wide strips along the planting rows. In areas with superficial soils or non-compacting (sandy textured) soils with little organic matter and minor plant cover, planting may be carried out without pre-plantation cultivation (Ricard 2003).

If the previous cultivation has been woody, all the roots should be extracted in order to prevent the proliferation of *Armillaria* sp. or other pathogenic fungi in the roots.

In order to cultivate truffles in acidic soil it is necessary to compensate by raising the pH. This should be calculated based on actual characteristics of the soil. A sample estimation would be 1 ton of a mixture in lime ($CaCO_3$) and calcium hydroxide ($Ca(OH)_2$) for every hectare in order to elevate the soil pH by 0.1 for the 20 cm of superficial soil (Hall and Brown 1989).

## 3.2 Acquiring the Plant

The host plant will be chosen based on the plantation site. In the nursery market, the available inoculated plants are several species of deciduous and evergreen oak trees including holm oak, hazelnut tree, and occasionally rockrose. Ideally, the chosen host should be the most suitable for the area. In Spain, best results have been observed with *Quercus ilex*, and it is not advisable to plant hazelnut trees (Estrada 1999), a species much more receptive to *Tuber brumale Vittad.* than the holm oak and downy oaks (Ricard 2003). In France, truffle production occurs earlier with holm oak than hazel nut trees, which would explain its higher concentration in newer plantations (Ricard 2003).

Plants should have a well-developed root system with abundant fine or trophic roots. The percentage of the total fine root tips colonized with *T. melanosporum* mycorrhizas should surpass 33%, and there should not be mycorrhiza from any other *Tuber* species. A low percentage of mycorrhizas from fungi commonly found in greenhouse conditions is acceptable although not desirable (Fischer and Colinas 1996). In the market it is easy to find a plant with truffle mycorrhiza percentages higher than 33% and relatively free of other fungal mycorrhizas. Seedling quality of the plants should be ideal and comply with current regulations and established forestry standards. The plants should be correctly stored and hardened-off, above all if they are to be planted in autumn. If seedlings are not certified, it is advisable to have the plants analyzed in a laboratory of his or her choice to confirm the seedling quality and mycorrhizal status of the plants prior to outplanting.

## 3.3 Selecting Planting Density

The planting density depends on the chosen host plant and the fertility of the land, which in turn is dependant on the depth of the soil as well as the content of organic matter and clay in the soil. Density should be lowest in areas of long growing seasons where higher annual tree growth is expected.

Density also varies according to the weed control model. For this reason, if one is considering cultivating the land often, it is best to space the trees accordingly. In the past, 5×5 m planting spacings were used to obtain densities of 400 plants/ha (Estrada and Alcántara 1990) and even greater ones of 400–600 (Grente and Delmas 1974) up to a total of 800 plants/ha (Nicolás 1973).

Currently the most widely used planting grids are those required to obtain a density of 200–330 plants/ha. This is achieved by using spacings of 6×5, 6×6, 7×5, etc.

### 3.4 Planting Time

According to the weather of each region, planting should be carried out from the month of November until the month of March and even up to April if there is late freezing.

### 3.5 Planting

The day before planting it is best to water the plants so that the root plug is more intact and to reduce potential transplant shock. Plantation should not be undertaken during freezing periods or with strong winds. Planting is carried out manually. Make a hole large enough to contain the plant. Carefully place the plant so that it sits vertically with its roots well extended in such a way that the root collar is slightly underground. Next, fill the planting hole with fine soil and pack it firmly by stepping around the plant to prevent air pockets. After planting it is advisable to water each plant with 5 liters of water. Protectors may be used if there is threat of animal browsing.

When planting in thin or superficial soils it is useful to place partially buried protectors around the plants in order to protect the plants against drought (Sourzat 2002).

## 4. Maintenance

Once planting has been carried out, the truffle plantation should be taken care of properly in order to obtain good production. For other types of cultivation there is a wide variety of information regarding proper treatments for plantations, and the response to such treatments is clearly observable: one can directly observe tree growth in the field and determine if they flower or if their fruits grow in size. However, the objective of black truffle cultivation is to aid in the development of a fungus that develops underground and is therefore not directly observable. The first indication of effective fungal growth is the appearance of the burn between the fourth and seventh year, although this does not guarantee the plantation's success. The first truffles usually are not produced until the middle of the sixth and tenth years. Until then, in order to follow the development of the fungus, one may observe the proliferation of mycorrhizae in the tree's roots, or detect the presence of mycelium in the soil by using molecular techniques (Suz et al. 2006)

## 4.1 Weed Control

### Stage 1: From the Establishment of the Plantation to the Appearance of Burns

In this stage the weed control around the plants is independent from the vegetation management or weed control model chosen later. During the first 2–4 years it is important to keep the area around the plants free of weeds using manual hoes. This way, it will help the plant's chances of survival by eliminating competition for water and nutrients while increasing survival and proliferation of mycelium.

In the separate rows between each plant the land should be cultivated with tools that can be controlled for depth – cultivators or disc harrowers (never a rototiller, which mixes the soil) – to a depth no greater than 15–20 cm (Reyna 2000).

The Tanguy method is used in some plantations in France: For the first two years of planting the herbaceous vegetation around the trees is eliminated with a hoe or by using herbicides thereby aiding in the survival and good establishment of the trees. On the third year, hoeing should be stopped to limit the growth of trees. The plantation is maintained with naturally occurring or seeded grasses. With the onset of truffle production a few cultivator passes can be made to stimulate new root growth (Sourzat 1999; 2000).

### Stage 2: Years Following the Appearance of Burns

Once the burn appears there are two options for weed control.

*a) Land cultivation:*
The objectives of truffle bed cultivation include: elimination of weeds and plants that compete with truffle mycelium and oak seedling for water and nutrients, promotion of soil aeration and improvement of the water-holding capacity of the soil.

Cultivation is carried out with depth-control tines to a depth no greater than 10 cm (Sáez and de Miguel 1995; Reyna 2000), although according to Carbajo (1999a), deep land cultivation helps the production of truffles.

However, excessive cultivation (3–4 or more times per year) may have a negative effect on the structure and porosity of the soil because of the destruction of soil aggregates, increasing compaction and a diminishing of microbial activity (Ricard, 2003), resulting in the opposite effect sought for in truffle bed cultivation.

Sourzat (2000) has observed that cultivation helps to produce larger sized truffles, although it does not favor the onset of production and in some situations may even delay it.

Land cultivation may be altogether unnecessary in sandy or extremely loose soils where there is good natural aeration (Ricard 2003).

The best times are the months of March-April (Sourzat 1997).

*b) Grass cover:*
Once the trees have developed burns the cultivation activity is halted, allowing for herbaceous plant growth, which can be controlled, if necessary, by mowing. Both naturally occurring and artificially sown grasses can be effective (Sourzat 2000). Contrary to land cultivation, the grasses aid in the development of biologic activity and microflora populations in the soil, which later become increasingly important for the development of the truffle fruitbodies (Ricard 2003).

## 4.2 Irrigation

### Stage 1: Establishment and Preproduction

Regular watering is recommended for the first years until the root system is well-established (Fortuny and Estrada 1986). Particularly during the first year or in the case of a prolonged drought of 20 days or more the plants should be watered depending on soil type and climatic conditions. There are two types of recommendations for the quantity of water necessary. The first is based on a volume of water per plant and the other on the water deficit of the plant calculated according to potential evapotranspiration. For the former, 3 to 4 litres is recommended per plant every two to three weeks depending on the intensity of the drought (Sourzat 2002). For the latter, it is recommended to reduce by one half the amount of water shortage registered (Bonet et al. 2005), especially in the spring and the first half of summer (Olivera et al. 2005). The first type of recommendation is useful when one cannot estimate the water shortage, but it is problematic because the necessary quantity of water depends on the type of soil.

If watering cannot be done, the plants should be mulched. Mulching does not appear to adversely affect the fungus, but it is not advisable to maintain the mulch for prolonged periods (Richard 2003).

### Stage 2: Production

In this stage the plants should be irrigated with 50–60 l/m$^2$/month from May–June until August–September (Grente and Delmas 1974; Olivier et al. 1996), or 30l/m$^2$ every 15–20 days (Sourzat 1997), 30l/m$^2$ every 3 weeks (Fortuny and Estrada 1986) or between 30–50 l/m$^2$ each month based on the soil's ability for water retention (Verlhac et al. 1990). With these quantities one must subtract the actual rainfall (Estrada and Alcántara 1990; Sourzat 1997). Carbajo (1999b) recommends 25 l/m$^2$ every 15 days during the months July, August and September, although each truffle farmer has his or her own particular guideline (Olivier et al. 1996). However, excessive irrigation appears to inhibit the production of truffles (CTIFL 1988). Presently, sprinklers or micro sprinklers are recommended over drip irrigation. Mulching with straw or other plant materials can help prolong the humidity of the irrigation and may be kept in place for the entire summer but without covering the entire burn. Diameters of about 50 cm of mulch material should be spaced out at a minimum of 60 cm intervals (Callot 1999; Ricard 2003).

## 4.3 Fertilization

Most soils have sufficient amounts of nutrients for black truffle development (Reyna 2000). The black truffle is a fungus adapted to living in marginally fertile or poor soils. It is advisable to fertilize only on plantations with land exceptionally low in a particular nutrient in order to make up for the deficit (Olivier et al. 1996). One common practice in areas with low soil pH is to gradually add slow-release calcareous corrections of around 1000 kg/ha of $CaCO_3$ before cultivating the land (Ricard 2003).

### 4.4 Pruning

For the first years of the plantation tree pruning is carried out primarily for correcting structural defects (Sourzat 2000; 2002) and to develop the desirable tree form for creating conditions most favorable for truffle development (Ricard 2003).

Formation pruning or early training is aimed at attaining a tree with the shape of an inverted cone (Carbajo 1999b) or oval shape (Grente and Delmas 1974) thereby eliminating lower branches and basal sprouts. Thus, the amount of light reaching the ground is increased, there is room for a later irrigation system and future truffle gathering is more efficient.

Formation pruning may begin in the third year depending on the plant's strength and should be done with low intensity. It is recommended yearly.

Later, at the onset of the tenth year, one should try to limit tree growth and expansion of the root system and avoid canopy closure (Ricard 2003). During this stage, pruning may be more intense and be necessary every 2–5 years (Reyna 2000).

In hot climates and with strong solar radiation one can prune the higher branches of the tree in order to aid aeration and conserve lower branches. This shades the ground and promotes a buffering of temperature extremes (Ricard 2003).

Pruning is recommended during the winter or the vegetative dormancy phase (Sáez and De Miguel 1995), although one can also prune in summer periods. Green pruning consists of a light pruning and pinching-off of the spring or summer growth before lignification (Ricard 2003).

### 4.5 Plagues and Diseases

The trees used in truffle cultivation are hardy species and small attacks from pathogenic organisms do not generally cause any loss (Ricard 2003).

With younger plantations during the establishment phase severe attacks that could disrupt tree growth may cause concern. Only in this situation is it necessary to intervene (Ricard 2003). In the production stage, the worst problems arise from possible truffle predators, mainly the wild boar, for which fencing is advisable (Reyna 2000).

In truffle cultivation, one should not aggressively attack plagues and diseases, since every treatment applied may affect the truffle ecosystem.

### 4.6 Productive Plantations

Onset of truffle production is variable. It is not uncommon for a few filbert or oak trees within a plantation to produce an early truffle 3–5 years after outplanting, but most plantations require 7–10 years before truffle collections will be reliable. Reports of truffle yields range between 50 kg/ha from well-managed 13–14 yr-old plantations in Italy (Bencivenga and Di Massimo, 2000), 45 kg/ha reported from irrigated plantations in Spain (Carbajo, 2000) and 15–50 kg/ha with exceptional yields up to 110kg/ha in 14 yr-old plantations in France (Chevalier and Frochot, 1997). Plantations may remain productive up to 35 years, but longevity depends very much on management interventions that can maintain healthy host trees and the soil parameters ideal for *T. melanosporum* habitat.

There is wide variation in annual production related primarily to climatic conditions. Summer rains have been positively correlated with truffle production. (Reyna 2000). In 2005-06, after a severe summer drought, truffles were collected from irrigated sections of mature plantations in Sarrión, Spain while the non-irrigated sections of the same plantation had very minimal production.

Truffles are collected between November and March with the assistance of a trained truffle dog. A specialized long-nosed trowel is used to remove them from belowground, and the dig is closed immediately afterward to maintain the integrity of the soil environment.

Truffle quality is also highly variable. Smaller and knobbier specimens are collected from very rocky and dry soils whereas larger and more regular-shaped truffles, which appeal to restaurant clientele, are found in spongier soils. Superficial truffles may be more vulnerable to freezing and lose the appreciated mature quality found in specimens collected from 10-15cm deep.

## 5. Cost-benefit analysis

The total yield on the initial investment is calculated by obtaining the annual yields from differences in income and expenses and discounting according to the value of the euro in the first year of establishment. According with our calculations, the total yield of one hectare of T. melanosporum according to the Net Present Value (NPV) is 50 231 € which corresponds to an annual net cash flow of 2691 €/ha.

This cost-benefit analysis gives an orientation of potential yields, given that we assume that the price of truffles and production quantities are constant. There are various studies which discuss profits obtained from plantations in Spain, France and Italy which show Net Present Values fluctuating between 19 424 €/ha and 66 972 €/ha (Bonet and Colinas 2001, including references cited therein). According to these studies, the average yield obtained using the internal rate of return (IRR) is always greater than 9% and the period of recuperation from the investment is always greater than 10 years.

## 6. Future prospects

The international market demand for fresh truffles and truffle products appears to be strong and the expansion of truffle plantations throughout regions of Spain, France and Italy continue. There are productive black truffle plantations in New Zealand, Australia and the USA, established in soils that require additional living to maintain the alkaline pH suitable for *T. melanosporum.* There are economic challenges for truffle producers to maintain a regular and quality product that will ensure a reliable income. This requires more rigorous studies on the influences of management interventions including irrigation, weed control, tree pruning and soil amendments. In addition truffle producers may be at a disadvantage when selling their products at local markets when they could fetch higher prices by selling quality truffles directly to the final buyer or consumer. This may require the introduction of grading truffles by quality and entrepreneurship on the part of the growers.

There are many ecologic challenges as well. Despite the large number of hectares in production, there are many plantations that fail to produce truffles. These non-productive sites challenge our understanding of the truffle's life cycle and biological requirements. Another ecologic challenge is the protection of the *T. melanosporum* habitat from invasions of other black truffles (Murat et al. 2008), particularly *T. brumale* and *T. indicum.* This will require more effective control over the of the inoculation material used for commercial truffle-colonized seedlings.

## Acknowledgements

This study has been funded by the Departament de Medi Ambient i Habitatge and by the Department of Agriculture of the Generalitat de Catalunya.

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# Acorn Production in Iberian Dehesas

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## Abstract

Acorn production is one of the most important products in Mediterranean agroforestry systems. In this work we present a review on the state of the art of fruit production of the Iberian *dehesas* of *Quercus ilex* (holm oak) and *Quercus suber* (cork oak). We briefly describe the common acorn production estimation methods, indicating their advantages and disadvantages. We also analyze the main known factors reported in the literature that determine acorn production such as pruning, stand characteristics, and site quality. The scientific review is complemented with the description of the preliminary results of some trials carried about to analyze the distribution of production over time and the effect of pruning. Acorn production is very variable both in time and space between individuals. Most studies found in the literature are too short and generally do not characterize the stands dasometrically, making it impossible to extract valid conclusions. Although it would seem strange to think that such a valuable resource is not well understood, the current situation is that there is a great lack of scientific knowledge on the ecology of acorn production in *dehesas*. Management and even the available literature keep relying on traditional empirical beliefs that should be demonstrated.

*Keywords: fruit yield; oak woodlands; agroforestry systems.*

## 1. Introduction

The genus *Quercus* (oaks) is one of the most widespread in the Northern Hemisphere, oaks being the main components of the tree stratum in many forests and woodlands. In Europe, and specifically in the Mediterranean basin, despite the great importance of oaks, there have been few studies of acorn production, even though acorns have played a basic role in domestic and wildlife feeding. As a consequence of its importance, many studies are available about the acorn production of many oaks in North America (Aizen and Woodcock 1992; Koenig et al. 1994; Abrahamson and Layne 2003) and in East Asia (Maeto and Ozaki 2003).

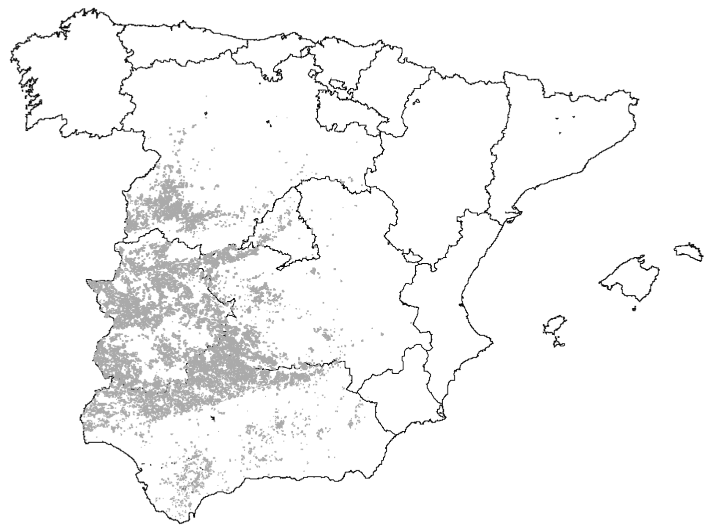

**Figure 1.** Distribution of the dehesa system in Spain (data from the Spanish Forest Map and the Andalusian Vegetation Cart).

The *dehesa* is a traditional agroforestry system which consists of an oak woodland with an understory composed of a mosaic of croplands, grasslands and shrublands, where cattle, sheep, pigs and goats are extensively raised (Joffre et al. 1988; San Miguel 1994). This agroforestry system occupies more than $3\times10^6$ hectares in the south-west Iberian peninsula. The mean tree density is around 30–50 trees $ha^{-1}$, varying from isolated trees to complete tree cover (over 100 trees $ha^{-1}$). Several tree species are present at the dehesa systems but perennifolius *Quercus ilex* L. (holm oak) and *Quercus suber* L. (cork oak) are the dominant tree species. In Table 1 the dasonomic characterization of the *dehesa* system is presented trough the available information of the third National Forest Inventory (IFN). Pruning to obtain firewood is a traditional activity which has been retained even though firewood has lost almost all of its value. Game, both small and large, is gaining importance as an income source, due to the changes in socioeconomic structure which have occurred over the last four decades (Pinto-Correia 1993; San Miguel 1994). The distribution of the Spanish dehesa is shown in the Figure 1.

The most characteristic fruit of the *dehesa* is the acorn, which is a key feeding resource in areas of mild winters. Acorns with the highest nutritional quality are those of the evergreen oak (*Quercus ilex* sbsp. *ballota*), followed by those of the quejigo oak (*Quercus faginea* sbsp. *broteroi*), cork and pyrenean oak (*Quercus pyreniaca* Willd.). It is considered that 9 kg of evergreen oak acorns are equivalent to 12 kg from the quejigo oak, 14 kg from the cork oak and 18 kg from Pyrenean oak. As fodder, the acorn is poor in proteins and rich in carbohydrates which are easily transformable into fat. It is therefore usually used for fattening fully-grown animals. Its energy value is about 0.5 UF/kg. The stock which make best use of the *montanera* (acorn-feeding period) on the dehesa are pigs, particularly of the Iberian breeds, which transform approximately 7–9 kg of acorns into 1 kg of high quality live weight, consuming about 8–10 kg of acorns per day for each 100 kg of live weight, all within an extensive system of exploitation, and generally without supplements. For other livestock, the *montanera* is only a complement of varying degrees of importance in its feeding.

**Table 1.** Dasonomic characterization of the dehesa system of holm or cork oak in Spain (5144 plots of the third Spanish National Inventory).

| | Mean | Median | Range | Std.Dev. |
|---|---|---|---|---|
| N (stem/ha) | 59.6 | 47.5 | 199.9 | 43.75 |
| Dg (mm) | 410.8 | 386.1 | 1526.0 | 155.76 |
| BA ($m^2$/ha) | 6.5 | 5.5 | 49.8 | 4.05 |
| Fcc (%) | 69.9 | 85.0 | 100.0 | 30.33 |
| H (m) | 7.6 | 7.4 | 21.2 | 1.88 |
| Dm (mm) | 431.8 | 418.8 | 1526.0 | 147.26 |
| Ho (m) | 8.9 | 8.5 | 28.0 | 2.43 |
| Do (mm) | 555.2 | 530.5 | 1526.0 | 188.53 |

N: number of trees by hectare; Dg: quadratic mean diameter; BA: basal area; Fcc: cover fraction; H: mean height; Dm: mean diameter; Ho: dominant height; Do: dominant diameter.

**Table 2.** Chemical composition (%) of holm oak and cork oak acorns (in bracket the mean standard deviation) (Cañellas et al. 2003).

| | Holm oak | | Cork oak | |
|---|---|---|---|---|
| | endosperm | shell | endosperm | shell |
| Humity (%) | 36.2 (0.55) | 26.5 (3.02) | 33.4 (0.98) | 17.1 (0.19) |
| Ash | 2.5 (0.15) | 2.1 (0.17) | 2.1 (0.38) | 2.2 (0.16) |
| Fat | 9.2 (0.45) | 1.5 (0.08) | 9.0 (0.60) | 1.7 (0.08) |
| Crude fiber | 4.0 (0.80) | 42.7 (1.52) | 2.0 (0.40) | 31.5 (1.28) |
| Crude protein | 6.0 (0.29) | 5.5 (0.27) | 8.1 (0.32) | 6.3 (0.32) |
| Ca | 0.39 (0.01) | 0.58 (0.02) | 0.30 (0.02) | 0.54 (0.02) |
| P | 0.81 (0.02) | 0.50 (0.02) | 1.30 (0.03) | 0.30 (0.02) |
| Mg | 0.80 (0.02) | 1.00 (0.04) | 0.76 (0.03) | 1.00 (0.05) |
| Fe* | 40.0 (1.7) | 57.0 (1.7) | 30.0 (1.2) | 50.0 (0.8) |
| Cu* | 90.0 (4.9) | 125.0 (7.0) | 125.0 (9.8) | 91.0 (10.2) |

* ppm

Acorn collection is usually from October to January (inclusive). The first falling acorns are usually green (with a high tannin content which may affect the livestock) or affected by *Balaninus* spp. Acorn production on the *dehesas* is believed to be concentrated on a limited number of individuals. This has led researchers to focus on the study and selection of high productive individuals or varieties for reproduction and for use in reforestation projects.

In this work we present a review on the state of the art of fruit production of the Iberian *dehesas* of *Quercus ilex* (holm oak) and *Quercus suber* (cork oak). We briefly describe the common acorn production estimation methods, indicating their advantages and disadvantages. We also analyze the main known factors reported in the literature that determine acorn production such as pruning, stand characteristics, and site quality. The scientific review is complemented with the description of the preliminary results of some trials carried out to analyze the distribution of production over time and the effect of pruning.

## 2. Estimation methods for acorn production

The estimation of acorn production is a laborious activity due to the large samples required and the demand of great effort to collect acorns. Different estimation techniques have been developed in technical and scientific works (Gea-Izquierdo et al. 2006): (i) visual survey and (ii) acorn collection.

(i) In the visual surveys methods, acorns are counted directly from the crown. Counts are made during a fixed time period, in sectors of the crown or in quadrats (Koenig et al., 1994; Perry and Thill, 1999). Score methods, subjective visual estimations, are included in this group too, which are made from standing crops according to ranked categories based on the amount and distribution of acorns in the crown. Several kinds and numbers of scores (generally between 4 and 10 categories) have been used in the literature (Perry and Thill 1999, 2003; Peter and Harrington 2002).

(ii) Acorn collection methods can be partial or total collection. In partial acorn collection seed traps or quadrats (ground plots) are evenly distributed beneath the crown. The number of traps or quadrats is preferably proportional to the crown area (Gysel 1956; De Zulueta and Cañellas 1989; Perry and Thill 1999). In the total acorn collection methods all acorns have to reach the ground, either naturally or man induced by using sticks, and they are collected in canvases placed beneath the crown (Gysel 1956).

The estimation method will be selected depending on the goals of the study and conditions such as economy, time, availability of trained workers and the scientific accuracy required. No method is perfect and each one can be suitable for a specific purpose. Visual methods are biased if the procedures are not standardised and the observers well trained before the survey, but it permits increasing sample size with very low cost. In traps, only acorns reaching the ground are collected, hence results are biased from aerial consumption by animals. If we aim at estimating the total production, as kg/ha or kg/tree, every method except the total counts requires a previous estimate to relate either the total acorn production or the production per surface area to the estimative method (scores, counts, traps or quadrats) selected, which adds an extra source of error. The total collection method is the most accurate one. Nevertheless, it requires the highest effort and, like all collection methods, does not permit the estimation of acorn yields in advance.

## 3. Acorn production

Oak acorn production of any of the species thriving on *dehesas* has not yet been well described. The time series studied are far too short to provide any clear explanation to acorn production (Gea-Izquierdo et al. 2006). The great variability reported by all authors (Martín et al. 1998; Álvarez et al. 2002; Carbonero et al. 2002; Torres et al. 2004), both between individuals and within individuals between years, is common to most other woody species (Herrera et al. 1998; Koenig and Knops 2000). Holm oak acorn annual mean values in *dehesas* in the literature are between 80 and 300 g/m$^2$ (Table 3). These figures are higher than the production in forests of NW Spain and SW France reported by Siscart et al. (1999). However, coefficients of variation over 100% are fairly common in the bibliography. Within the same location it is possible to find individuals with null annual production and trees producing up to 155 kg/tree (Carbonero et al. 2003). In the northwest foothills of the Central Range System (northernmost range of dehesas, Salamanca province), Álvarez et al. (2002) report ranges from 0.1 to 87.9 kg/tree, corresponding to an average of 19.0 kg/tree. These results are similar to some studies, with a tree annual production in 6 years of 20.7 kg/tree

**Table 3.** Acorn production of Western Iberian holm oak woodlands from different sources (from Gea-Izquierdo et al. 2006). Data are averages of several years and different stands. Means of annual standard deviations (SD) as simple estimates of dispersion are between brackets; they were weighted by number of years estimating production when possible.

| References | Procedence | Sample size (trees) | Estimation method | Nºof years | Stand density (trees/ha) | Mean production g/crown m$^2$ | Mean production kg/tree | Mean production kg/ha |
|---|---|---|---|---|---|---|---|---|
| Porras, 1998 | Huelva | 140 | Total acorn collection | From 8 to 2 | - | - | 22.9 (10.8) | - |
| Álvarez et al. 2002 | Salamanca | - | Total acorn collection | 1 | 25 | - | 19.0 | 475 |
| Gómez et al. 1980 | Salamanca | 3 | Traps | 2 | - | 86.6 | - | - |
| Escudero et al. 1985 | Salamanca | - | Traps | 3 | - | 120.1 | - | - |
| Martín et al. 1998 | Sevilla | | Traps | 7 | 23 | 285.8 (194.5) | 25.3 (6.5) | - |
| | | - | | | 60 | 115.8 (83.2) | 7.1 (1.9) | - |
| Carbonero et al. 2003 | Córdoba | 50 | Traps | 2 | 60-78 | - | 26.7 (5.1) | - |
| Torrent, (1963) | Spain | 2000 | - | | | | | |
| Olea et al. 2004 | Badajoz | - | Traps | 2 | 20-45 | - | - | 674.3 (120.4) |

(Medina-Blanco 1963), from the Central West Range of *dehesas* (Extremadura), but higher than other results in that same area (15 kg/tree; Espárrago et al. 1993). In *dehesas,* within 8 provinces of Spain, in 10 years, Torrent (1963) visually estimated a mean annual average of 586.4 ± 131.6 kg/ha and similar average values around 550 kg/ha have been reported by other authors (San Miguel 1994; Martín et al. 1998. Table 3).

## 4. Tree and stand production

### The Effect of Tree Density and Stand Characteristics

Acorn production is likely to vary with stand density. Table 3 shows some of the studied relationships between acorn production and stand characteristics for the *dehesa* system. Martín et al. (1998) estimated a holm oak annual production per crown unit area ranging from 0.5 to 577.2 g dry matter/$m^2$. Holm oaks in stands of low density (23 trees/ha) averaged higher productions per tree (285.8 g/$m^2$, 25.3 kg/tree). However, these trees produced less per ha (291.5 kg/ha) than stands with higher densities (59.5 trees/ha), which had the opposite trend (115.8 g/$m^2$; 7.1 kg/tree; 296.0 kg/ha). The same negative relationship was observed for cork oak stands in the same area.

Lower densities seem to account for higher production at tree level, as a result of increased light availability (Abrahamson and Layne 2003), and decreased intraspecific competition. In North America (Healy et al. 1999; Perry and Thill 2003) and Central America (Guariguata and Sáenz 2002) several oak species average higher productions after thinning, and it has also been shown in two North American *Quercus* species how acorn production decreases with increasing stand basal area (Perry et al. 2004). In holm oak closed forests with 1,400 trees/ha in France, the average reported is 512.3 ± 365.5 kg/ha-year (Lossaint and Rapp 1978). Abrahamson and Layne (2003) also detected that stand diameter distribution is also likely to affect acorn production. Tree diameter is directly related to crown volume and age. In other oak species it has been shown that the larger the dbh, the higher total tree production (Greenberg 2000). However, factors as tree dbh, crown volume, and tree age have sometimes contradictory effects into production per crown $m^2$. Some authors have stated that trees with dbh under 25 cm are significantly less productive per crown unit area (Greenberg, 2000; Carbonero et al. 2002; Alvarez et al. 2002) (Figure 2). This fact could be related to the first age of flowering of trees and maturing of individuals, and should be studied in more detail.

### The Effect of Site

The relationship of acorn production to site characteristics (climate and soil) has been widely reported in other species, showing a great influence in acorn production (Kelly and Sork 2002; Abrahamson and Layne 2003). There is yet a lack of studies analyzing this aspect in the *dehesa* system. Álvarez et al. (2002) in Salamanca (Fig. 2) observed differences in acorn production between stands thriving on slopes, plains and foothills. There were soil differences among the topographic situation (foothill soils have higher clay and loam percentages while slopes tend to be more sandy and acidic) and stands characteristics. Similarly, Carbonero et al. (2004) reported higher production in heavy soils (loamy-clay soils or clay), than in sandy or sandy-loam soils. Siscart et al. (1999), in holm oak forests of NW Spain, reported an increase in acorn number and biomass in nitrogen fertilized plots. In the same study, irrigation was found to be closely related to fertilization and annual acorn production affected positively

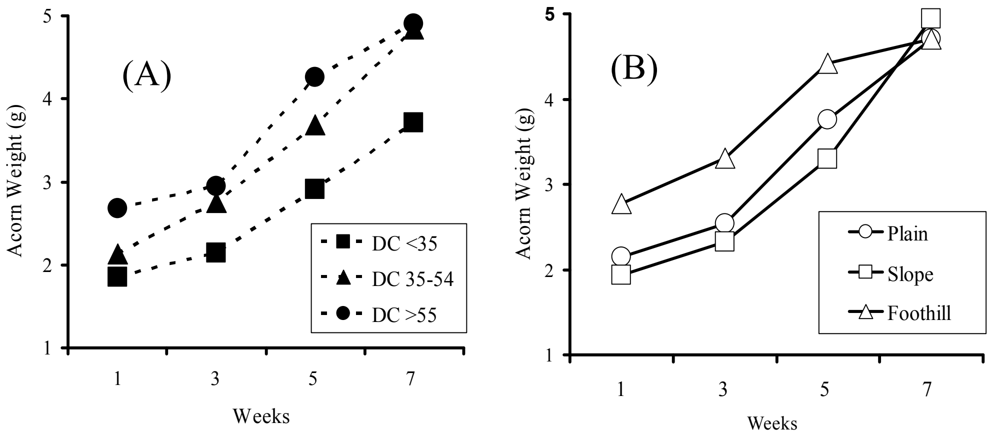


**Figure 2.** Variation in acorn weight (g) along the fruiting season (weeks in the x-axis, from 15-october to 15 December). Data from Álvarez et al. (2002) from a sample 100 acorns per tree of 44 trees belonging to three stands in different positions (slope, plain, foothill) in one year in Salamanca (Northern limit of dehesas). (A): effect of diameter class. (B): effect of position.

only in years with high summer drought. According to the previously discussed, masting would be likely to be more pronounced in the highest elevations, as lower productivity increases the time required to accumulate resources between high seed crops (Kelly and Sork 2002; Abrahamson and Layne 2003). Some authors have studied the relationship between fertility and acorn production in *dehesa* systems (Martín et al. 1998; Carbonero et al. 2004) but neither of them found any significant effect.

## Other Factors Affecting Acorn Production

Some other factors affecting acorn production have been studied such as the position of acorn within the canopy (Innes 1994; Nuzzo et al. 1997; La Mantia et al. 2003). Peter and Harrington (2002) found higher acorn production in the top half of the canopy in *Quercus alba* stands. Carbonero et al. (2002) report a non-significant increase in both the outer part and the south facing part of the crown (29.6 g/m$^2$ in the South-outer; 26.4 g/m$^2$ in the North-outer; 21.2 g/m$^2$ in the South-interior; 20.4 g/m$^2$ in the North interior) in holm oak trees in *dehesas*. These differences could be a result of higher light availability (Guariguata and Sáenz 2002) as acorns in the more shaded branches receive less light for maturation, in a similar way to subcanopy tree species (Kato and Hiura 1999). Additionally, branches located in different orientations receive different quantities of sap (Infante et al. 2001). Therefore, it might be thought that South and South West aspects would be more productive. Pre-dispersal and post-dispersal acorn losses owing to biotic and abiotic factors can reduce yearly acorn production (Pulido and Diaz 2005). Insect attack provokes an early fall of acorns (Soria et al. 2005). The negative effect of insects can be very intense some years, with reductions in acorn yield up to 50% (Espárrago et al. 1993; Soria et al. 1996, Cañellas et al. 2007), however these figures are likely to increase in some years attending to results in other European oak species (Crawley and Long 1992). Some authors report an adjustment of some insect life-cycles to two or more year patterns, suggesting that insects would synchronize

**Table 4.** Average tree characteristics of the cork oak pruning trial plots. Standard deviations are between brackets (from Cañellas et al. 2007).

| variables | Treatment | |
|---|---|---|
| | pruned | No pruned |
| Circumference over cork (cm) | 134 (30) | 141 (29) |
| Circumference at the top of trunk over cork (cm) | 126 (34) | 135 (37) |
| Circumference in mid-point of trunk over cork (cm) | 122 (34) | 127 (34) |
| Circumference at the base of trunk over cork (cm) | 147 (41) | 157 (37) |
| Height stripped in trunk (cm) | 247 (68) | 264 (95) |
| Stripping coefficient* | 2.10 (0.5) | 2.22 (0.51) |

* Relation between stripping height and circumference over cork at 1.3 m

their diapauses to fruit masting (Maeto and Ozaki 2003). The exudation of sap in acorns, a phenomenon called "drippy nut disease (*melazo*) possibly causing transmission of pathogens by insects, is another common source of acorn losses. In García et al. (2005) 27.5±10.7 % of trees produced acorns with *melazo*, which generally fall earlier from the tree. Other activities such as grazing and ploughing could influence acorn production but until now the effect of ploughing or fertilisation in this system has not been quantified.

Tree selection through centuries in *dehesas* could have led to a genetic differentiation compared to the original forest. However, to our knowledge, no studies have been conducted analyzing the effect of genetic selection and genetic tree variability on acorn production in this ecosystem.

## 5. Pruning effects in acorn production

The effect of pruning in Mediterranean oak woodland has long been controversial. There is insufficient information based on research even to form an objective and rational opinion upon the response of trees to this silvicultural practice. Light or moderate pruning are likely to be positive for the tree growth and production. Pruning of overshadowed and weak branches (with a negative energy balance, more carbohydrates are lost by respiration than gained by photosynthesis) is thought to be beneficial (Hubert and Courrand 2002). The economic costs of light or moderate pruning are very high, and there are attempts to compensate these costs by obtaining incomes from firewood, charcoal or virgin cork. This generally implies an increase in the intensity of pruning, which can be too intense and cause damage to the tree and produce an imbalance between the above and underground biomass. There is also a traditional belief that pruning increases acorn production (San Miguel 1994; Gómez and Pérez 1996). Acorn production is nowadays one of the most profitable products in the *dehesa* system, as Iberian pigs, the most efficient acorn consumers, are raised extensively by feeding them acorns during the fruiting period as it has been previously described.

To analyse the effect of pruning in acorn production in a cork oak open woodland a pruning trial was developed where acorns were collected from 40 cork oak trees pruned in December 1993, and 40 left un-pruned (Cañellas et al. 2007). Cork stripping took place in August 1998, at the end of a ten-year cycle. Trees were selected in pairs according to their size (circumference over cork at breast height), covering all the diameter classes present in the area. A moderate pruning treatment was applied, removing around 30% of crown

**Table 5.** The effect of pruning on acorn production (ANOVA) (from Cañellas et al. 2007).

| Year | Mean (g/m²) No pruned | Pruned | Average |
|---|---|---|---|
| 1994–1995 | 332.85 ± 340.02 a | 137.68 ± 322.13 b | 237.39 ± 343.73 |
| 1995–1996 | 0.74 ± 1.65 c | 2.10 ± 8.21 c | 0.98 ± 5.83 |
| 1996–1997 | 58.15 ± 115.02 d | 56.76 ± 108.39 d | 56.89 ± 111.13 |
| 1997–1998 | 31.02 ± 61.00 e | 32.85 ± 67.38 e | 30.98 ± 63.78 |
| 1998–1999 | 332.57 ± 312.21 f | 177.64 ± 167.91 g | 224.43 ± 264.27 |
| Average | 155.64 (77.59) | 81.21 (32.96) | |

Different letters indicate statistical differences at a = 0.05 between years (standard deviations). As the interaction between 'Pruning treatment' and 'Year' was significant, comparisons were calculated independently for each combination of factors

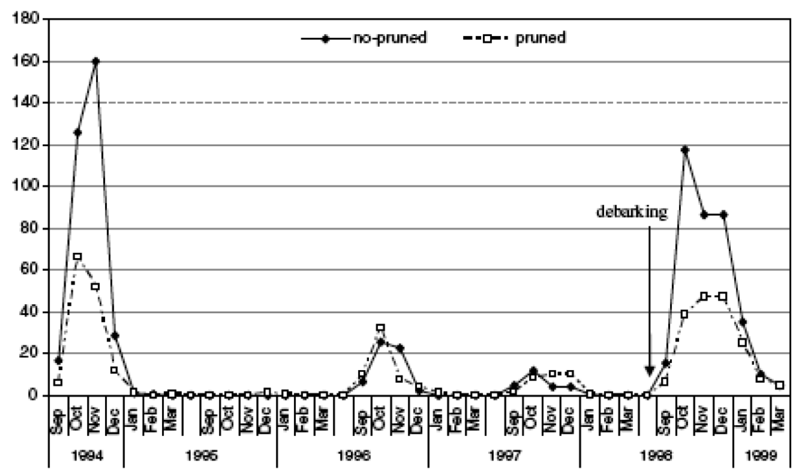


**Fig. 3.** Seasonal distribution of acorn fall in pruned and un-pruned cork oak trees (expressed in g m–2 of crown surface). Data from September 1994 to March 1999 (from Cañellas et al., 2007).

biomass. Acorns were collected in one 0.3025 $m^2$ trap per tree placed randomly below each tree crown (taking into account the distance to the trunk and the orientation). Falling acorns were collected monthly from September 1994 to March 1999. Acorns were dried at 80ºC for 48 hours and weighed to the nearest 0.01 g.

No significant effect on silvicultural characteristics such as tree size and intensity of cork stripping was observed between pruned and non-pruned trees (Table 4). The estimated acorn production (expressed in units per crown projection area) was analyzed through five annual cycles (1994–1999) as a function of the pruning treatment (Table 5). Acorn yield varied greatly between years. A large fall of acorns in 1994 was followed by a low fall over the next three years (Fig. 3). The interaction between 'Treatment' and 'Year' was significant ($F_{4,390} = 4.81$, $P < 0.001$), hence the pruning effects were analysed for each year separately (Table 5). There were significant differences in the years 1994 and 1998 (see Table 5) between the pruned and un-pruned trees, coinciding with the two years where acorn production was above the average. However, when acorn production was below the average (the other three years studied), production was unaffected by pruning.

Our results suggest that it is unclear whether pruning enhances acorn production, as is traditionally believed (San Miguel 1994). It is difficult to obtain any conclusions from the existing studies, as most of them lack many necessary details, such as production previous to pruning and stand characterization (especially tree diameter distribution and crown sizes), and do not study a whole pruning period (between 10 and 20 years). (Gómez and Pérez 1996; Álvarez et al. 2004).The present study also suffers from some of these shortcomings: there are no records from before the pruning and our study period is still too short to evaluate a whole pruning cycle. However, as an approach, this study is valuable as a basis for the necessary longer studies to demonstrate if there is a response in acorn production to pruning. Most authors report a decrease in production during the first year after pruning (Porras 1998; Carbonero et al. 2003; Álvarez et al. 2004). This might be explained as the tree reallocating resources to rebuild the aboveground biomass (Cañellas et al. 2007).

In our results, pruning clearly reduced production during the above the average ("masting years"), which could be partly a result of lower crown volume after pruning. There is no agreement between authors on whether the type of pruning used has an influence or not (Álvarez et al. 2004), but intuitively it could be thought that less aggressive pruning will be less negative for trees. Most pruning and production studies have been conducted on holm oaks. Flowering and fruiting phenology is more complex in the cork oak than in the holm oak (flowering and fruiting cycles of 1, 1.5 or 2 years), and this could influence any comparisons between the species. As the existence of a positive effect of pruning on acorn production is not clear, and currently charcoal and firewood are depreciated in value, pruning might be unprofitable from an economic point of view. Nevertheless it provides work for people in deprived areas which can temporally have socio-economic benefits.

## 6. Final remarks

The most important conclusion from this study should be the need of more detailed, longer studies to explain acorn production patterns in this Iberian ecosystem. The heterogeneity of methodologies and incomplete way in which results are reported in most studies makes the extraction of clear conclusions of any of the factors analyzed impossible. Acorn production is economically and ecologically important enough to deserve more attention that it has received so far. Specific, well designed studies are urgently needed if we want to approach the understanding of this phenomenon and all the details involved.

It is necessary to study in depth the effect of the main silvicultural treatments (fertilization, ploughing, pruning, density regulation,..), specially in a very harsh and changing ecosystem like the Mediterranean open landscapes. Traditional beliefs, though being a very valuable source of wisdom, must be analyzed and demonstrated.

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# The Chestnuts "*Filiere*" in Italy: Values and Developments

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## Abstract

Italy has an ancient chestnut producing tradition. Although its production has been slowly decreasing in recent years, because of the reduction of the land devoted to chestnut trees for fruits, today there is a new positive trend in the appreciation of this product. On the economic side, at chestnut orchard level, this crop is fairly satisfactory and rewarding but market margins are rather high along the *Filiere*.

A lot of problems, however, are still unsolved, such as the high cost of harvesting and other operations, due to the limited and difficult mechanisation, old and incoming new pests and pathogens and high seasonality of its market.

A possible way for improving the future of the chestnut *Filiere* is, of course, pooling producers' supply and generating a strong marketing action, aimed at the development of new processed products that present new appeal to the changing taste of consumers.

*Keywords: chestnuts economic results; Filiere development; marketing strategy*

## 1. Introduction

Italy has been, and still is, one of the largest chestnut producers in Europe but its production decreased for a long time. The land devoted to chestnut trees for fruit has also slowly decreased in recent years. It is seems that new interest is devoted to this production (Alvisi 1994), but is too early to substantiate it with appropriate statistics, particularly with reference to new processed products developed from chestnuts.

The production activity is mostly located in a few regions and single chestnuts orchards are limited in extension (80% of farms are within a range of 0–5 hectares), mainly located in low mountain and hill districts. Mechanisation is limited to the most relevant operation,

EFI Proceedings No. 57, 2009
Modelling, Valuing and Managing Mediterranean Forest Ecosystems for Non-Timber Goods and Services
Marc Palahí, Yves Birot, Felipe Bravo and Elena Gorriz (eds.)

**Table 1.** Chestnut orchard world surface (ha) (FAOSTAT 2007).

| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | World % 2006 |
|---|---|---|---|---|---|---|---|---|
| Bolivia | 25 000 | 25 000 | 25 000 | 25 500 | 25 500 | 30 116 | 30 116 | 8 81 |
| China | 110 000 | 110 000 | 120 000 | 125 000 | 125 000 | 125 000 | 126 000 | 36.87 |
| Italy | 23 500 | 23 500 | 23 500 | 23 500 | 23 500 | 24 000 | 24 000 | 7.02 |
| Japan | 26 400 | 25 900 | 25 600 | 25 300 | 25 300 | 23 800 | 23 300 | 6.82 |
| Korea | 38 000 | 39 000 | 35 000 | 35 000 | 35 000 | 38 783 | 38 783 | 11.35 |
| Portugal | 29 101 | 29 190 | 29 522 | 29 522 | 29 500 | 30 276 | 30 265 | 8.86 |
| Spain | 6 254 | 6 254 | 6 254 | 11 237 | 6 254 | 6 000 | 6 000 | 1.76 |
| Turkey | 35 300 | 35 100 | 35 100 | 35 300 | 35 300 | 35 816 | 35 816 | 10.48 |
| World | 319 914 | 320 932 | 327 335 | 333 388 | 333 605 | 341 613 | 341 698 | 100 |

harvesting. Because of steep slopes and terraces where the big trees are situated, harvesting is costly and highly labour intensive, so far mostly performed by elderly people, who will gradually abandon this activity (Alvisi 1979).

Chestnuts market reflects this situation and the bargaining power of single producers is very limited, unless they manage to organize themselves, pooling their produce. Post harvest operations, represented by water "curing" the chestnuts, does represent a possible source of savings by exploiting economies of scale, as is also the case for marketing operations, i.e. pooling the products allows to improve and/or establish market power in confronting the buyers, or the processing industry (Casini et al. 1990). Most farmers are price takers from local buyers and this makes it difficult to continue a profitable activity, or obtain a decent individual income. Moreover, the outlets for produce shows marked differences between the Centre-Northern producers and those in the South and Islands.

A possible solution and policy orientation, beside organizing producers, lies in the creation of Value Added to the raw material (chestnuts), by finding and promoting new processed products, by organizing high food quality campaigns and bringing back traditional dishes, which usually present a strong appeal to customers (Alvisi 1979; Bounous et al. 2001).

This paper aims at:

- exploring the state of art in the Italian chestnut *Filiere* (marketing channel);
- reviewing the present situation both in terms of income provision and market revenues;
- analyzing present and possible opportunities for consumption;
- proposing tentative policy options for enhancing both the value of the product and the development of this sector.

A last remark should be made in relation to statistical data reported in the following tables; the reader will notice discrepancies between FAO data and the national ones (ISTAT). A possible reason for that could refer to a communication gap and deferred transmission from one year to the other. All this could cause some confusion and will be explained further on.

### 1.2 Surface area and production

The chestnut tree (*Castanea sativa*) has Asian origins and was already in Europe in Roman times and at present is grown all over the world (Bounous 2002). Its product, the chestnut,

**Table 2.** Chestnut world production (tons) (FAOSTAT 2007).

| Country | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | World % 2006 |
|---|---|---|---|---|---|---|---|---|
| Bolivia | 34 400 | 34 500 | 34 500 | 35 000 | 38 788 | 40 980 | 40 980 | 3.47 |
| China | 600 371 | 601 242 | 703 849 | 799 811 | 807 753 | 828 130 | 850 000 | 72.05 |
| Italy | 50 000 | 50 000 | 50 000 | 50 000 | 50 000 | 52 000 | 52 000 | 4.41 |
| Japan | 26 700 | 29 000 | 30 100 | 25 100 | 24 000 | 21 800 | 23 100 | 1.96 |
| Korea | 92 844 | 94 130 | 72 405 | 60 017 | 71 795 | 76 447 | 76 447 | 6.48 |
| Portugal | 33 317 | 26 118 | 31 385 | 33 267 | 31 051 | 22 327 | 29 133 | 2.47 |
| Spain | 9 230 | 9 510 | 9 362 | 16 821 | 9 510 | 10 000 | 9 500 | 0.81 |
| Turkey | 50 000 | 47 000 | 47 000 | 48 000 | 49 000 | 50 000 | 53 814 | 4.56 |
| World | 943 983 | 936 708 | 1 021 659 | 1 125 915 | 1 128 254 | 1 148 588 | 1 179 727 | 100 |

has always enjoyed an important role in the economy of Italian rural areas, both in low mountain and hilly districts, as shown by FAO data, which places Italy amongst first in world rankings, both for orchard surface area and chestnut production.

All over the world there are about. 350 000 ha covered by chestnuts trees.

From Table 1, it is clear that there are two major poles: the Asian one, with China, Korea and Turkey, covering almost 60% of world total; the European pole, represented by Italy, Spain and Portugal.

The analysis related to production is not too different. World total production amounts to 1 200 000 tons. Again China is top ranking with a production of 850 000 t, 72%, followed by Korea, Turkey and Italy, which by yields overtakes countries with larger producing surface areas, such as Portugal and Bolivia.

Summing up, except for China whose recent increasing yields have been remarkable, the overall situation has been more or less stationary and, in certain cases, decreasing as in Japan.

A few words, however, have to be spent on data reliability. Tables referred to here are drawn from FAO source, good in the sense this makes it possible to achieve a comprehensive picture worldwide. However, these data are not trustworthy, for instance, at least in regards to the Italian situation. It has to be noted in fact that the yield data are continuously repeated, year by year, for too long a period, which seems at least a bizarre situation. Moreover, the Italian data appear different from those published by ISTAT, the Italian Central Statistical Institute, charged to transfer these agricultural statistics to FAO.

Analyzing the Italian chestnut production using ISTAT data, in the last decade it decreased from 60 000 t in the early 1970s to around 50 000 t in the middle of 2000s (ISTAT Agriculture Census 2000). Farms with chestnut trees amount to more or less 34 000 units in 2005 (ISTAT 2007 yearbook) with only 59 000 ha of intensive chestnut orchards.

Table 3 shows, in the period between 1970–2000, a strong decrease both in the overall number of farms (-51%) and in agricultural area (-47.6%). As previously mentioned, it has to be pointed out that this analysis is heavily in contrast with FAO data, proposed in Table 1 and 2.

The largest surface areas occupied by chestnut trees are in Tuscany, Campania, Calabria, Piedmont, Latium and Emilia-Romagna. In terms of yield, however, the picture changes quite drastically. Whilst Campania still stays on the top of the list, Tuscany contributes to national harvest only for 7%, while Latium produces 14% with much smaller surface areas

**Table 3.** Number of farms and average of chestnut orchards in Italy, 1970-2000 (ISTAT Agriculture Census 2000).

| Year | Farms (n°) | Total Surface (ha) | Farm average Surface (ha) |
|---|---|---|---|
| 1970 | 136 098 | 144 887 | 1.06 |
| 1980 | 119 553 | 140 133 | 1.17 |
| 1990 | 97 696 | 107 608 | 1.1 |
| 2000 | 66 213 | 75 985 | 1.15 |
| Variation1970–1980 | -0.122 | -0.033 | 0.101 |
| Variation 1980–1990 | -0.183 | -0.232 | -0.06 |
| Variation 1990–2000 | -0.322 | -0.294 | 0.042 |
| Variation 1970–2000 | -0.513 | -0.476 | 0.078 |

than Tuscany and Piedmont, given its particular pedo-climatic endowment. All remaining Regions keep the same relevance in yields as in surface areas.

In Latium there are 5 Provinces, but just 4 of these are involved in chestnut production. In particular, the largest number of farms is situated in Viterbo and Roma Provinces, but with some differences. First of all, the average farmer has a bigger surface area while in the latter there are many small farms, under one hectare.

The reason of Viterbo Province's leadership, both in the Region and, partially, at national level, is due to the particular orographical and pedo-climatic characteristics and, therefore, to its natural vocation for this crop.

Besides all that, a strong consideration to this situation comes from public authorities, first of all the Cimini Mountain Community, which for a long time has intervened with actions aiming at the enhancement of the orchard asset and has managed to rehabilitate more than 50.000 old chestnut trees and in so doing turning 20 000 ha of chestnut coppice into high stands.

Joint efforts, both from public and private authorities, have, moreover, managed to encourage mechanized harvesting (Dono et al. 2000), first processing of produce, organizing local meetings and festivals, boosting marketing campaigns for chestnuts and their sales (La Filiera del Castagno Laziale, DECOS – ARSIAL Project 2004).

## 2. The Filiere structure and background

More than 80% of national produce is eaten as soon as harvested, half in the home market and half exported. The fresh product can be eaten roasted , boiled, baked, cooked in milk and sugar or as a staple product in arranging first courses and accompanying second courses of meat (Carbone et al. 2000).

Of the remaining 20%, a small portion as 5–10% is dried, and the last quota is destined to the processing industry (Pinnavia et al. 2003).

The *Filiere* (marketing channel) can be sketched in the following way:

This arrangement is just an example of the most likely *Filiere* because, often, its actors can play more than one role (Carbone et al. 2000).

However, we can summarize the *Filiere* by two models:

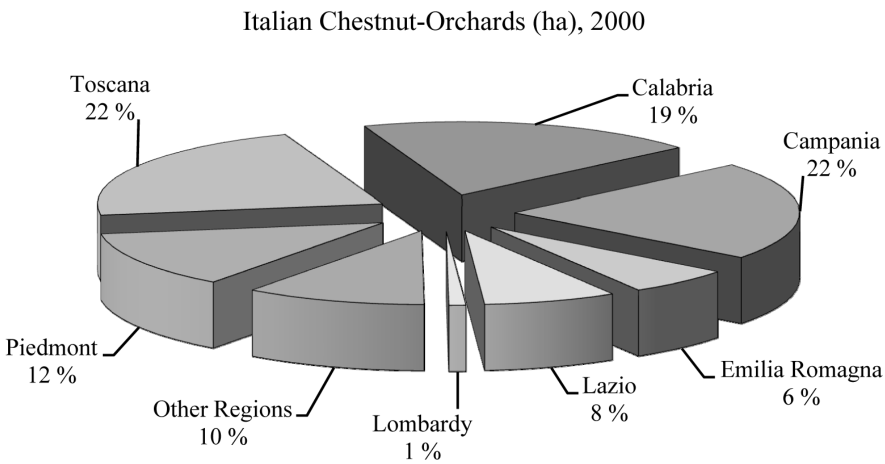


**Figure 1.** Italian Orchards Surface (ISTAT Agriculture Census 2000).

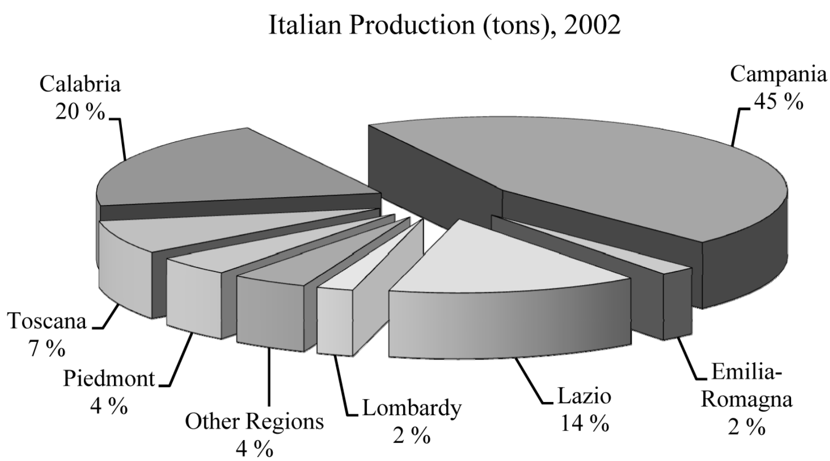


**Figure 2.** Italian Production (ISTAT 2002).

1. "Short *Filiere*" (on the right side of Figure 4) in which the farmer sells his product directly at consumers' price, gaining the entire added value. He can sell to:
   - restaurants
   - festivals
   - local associations for tourism development
   - retailers
   - local bakeries and confectioners
   - street vendors
   - consumers (friends, colleagues, etc.)
2. "Articulate *Filiere*" (on the left side of Figure 4) in which the number of agents increase with a lot of intermediaries, such as:

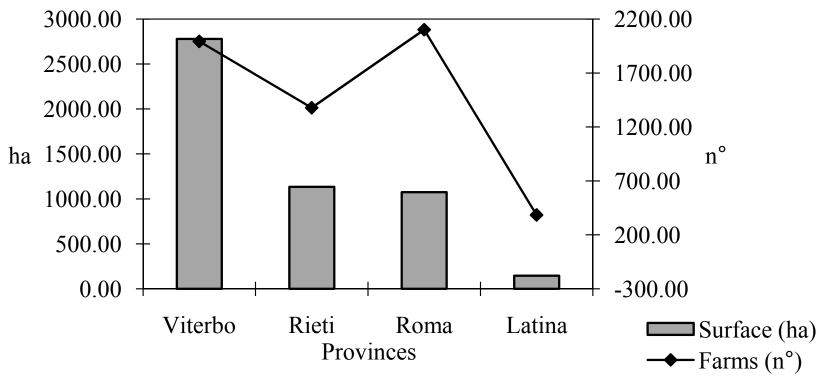


**Figure 3.** The Chestnut-Orchards in Lazio Regions (ISTAT Agriculture Census 2000).

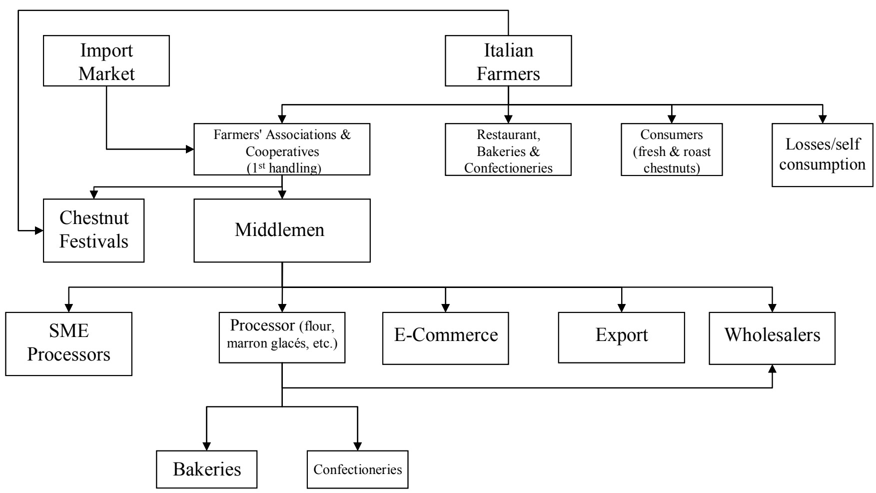


**Figure 4.** The chestnut Filiere.

- farmers' associations and coopertives (1st handling)
- processors
- middlemen
- wholesalers
- retailers
- e-commerce

After picking, the fruits need some treatment to preserve them. In fact, before falling, apart from climatic factors that have influenced their growth, the fruits have been threatened almost exclusively by pest developed from eggs laid when the pericarp was still white and tender. The handling operations consist of: sorting, washing, curing and packaging. In particular "curing" is a technique of submerging chestnut into water at 15 °C, for 4–5 days ,to preserve the fruits from pest developement. After curing, chestnuts are 3 or 4 times more resistent than those that have not been treated.

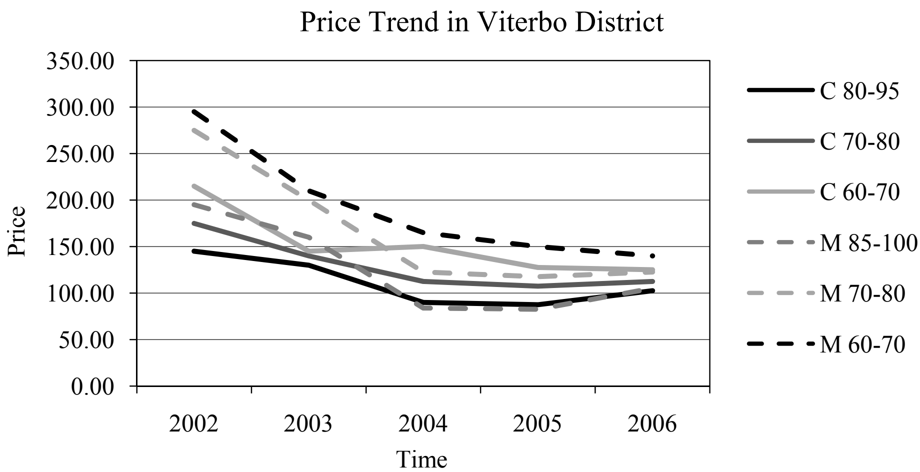


**Figure 5.** Price trend in Viterbo Province (Chamber of Commerce, Viterbo data). C=Chestnut; M=Marroni, units/kg.

Other processes depend on the kind of final product produced. In general, these are:

- drying and grinding process (flour);
- cooking with syrup (fruits in syrup, candied, *marron glacés*);
- cooking and homogenizing by steam and preservatives (creams and mashes);
- freezing (fresh and mashed products);
- ice creams.

Chestnut prices for the Viterbo district are reported in Figure 5. The graph obtained by average values, shows clearly the decreasing trend, but for a slight increase after 2004 for the lowest priced chestnuts and *marroni*.

It should be noted that in Italy the big size chestnut and the bigger and rounder marrone varieties are more expensive than other fruits; a difference, however, which is gradually closing, as it is shown in Table 4 (Pirazzoli 1991). A possible explanation to that lies in the consumers' reaction, in an overall income depression, in choosing the least priced chestnut and marroni and neglecting the higher priced products. Another hypothesis referes to the representativeness of the reported market prices, that is that they are relevant only for a wide section of the wholesale market, but they do not consider the direct sales of quality products made by large farmers to supermarkets or food chains, by-passing official records.

Data are in nominal terms, not deflated, which makes the decline even more relevant.

## 3. Basic material and discussion

Tables 5 and 6 provide details on costs of planting new orchards. Grafting coppices, the other alternative of establishing new orchards, is not considered in this paper and it appears to be not very suitable and successful. A new chestnut orchard does not start as usual with deep ploughing in order not to disturb mycorrizes and forest soil structure. Seedlings are just placed in deep holes (1×1×1m) at a distance of 10×10m (Casini et al. 1990).

**Table 4.** Wholesale prices (€/tons) in the area of Viterbo per size* and typology**, 2002–2006 (own arrangement from Chamber of Commerce, Viterbo data).

| Typology | Size | 2002 | | 2003 | | 2004 | | 2005 | | 2006 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | (n°/Kg) | Oct. | Nov. | Oct. | Nov. | Oct. | Nov. | Oct. | Nov. | Oct. | Nov. |
| Chestnut (C) | 80–95 | n.a. | 140–150.00 | n.a. | 125–135.00 | 90–95.00 | 85–90.00 | 85–90.00 | 85–90.00 | 100–105.00 | 100–105.00 |
| | 70–80 | n.a. | 170–180.00 | n.a. | 135–145.00 | 110–120.00 | 105–115.00 | 105–110.00 | 105–110.00 | 110–115.00 | 110–115.00 |
| | 60–70 | n.a. | 210–220.00 | n.a. | 140–150.00 | 140–160.00 | 140–160.00 | 125–130.00 | 125–130.00 | 120–130.00 | 120–130.00 |
| Marroni (M) | 85–100 | n.a. | 190–200.00 | n.a. | 155–165.00 | 80–90.00 | 80–85.00 | 80–85.00 | 80–85.00 | 100–110.00 | 100–110.00 |
| | 70–80 | n.a. | 270–280.00 | n.a. | 195–205.00 | 120–130.00 | 115–125.00 | 115–120.00 | 115–120.00 | 120–125.00 | 120–125.00 |
| | 60–70 | n.a. | 290–300.00 | n.a. | 200–220.00 | 150–180.00 | 150–180.00 | 145–155.00 | 145–155.00 | 130–150.00 | 130–150.00 |

* size: refers to the number of single pieces per Kg; it means that the more the chestnuts the least is their diameter;
** typology: refers to the difference in varieties , having the chestnuts a shape flat on one side, contrary to the marrone which is round on both sides.

**Table 5.** Cost of planting a new chestnut orchard* (MiPAF Project D.M. 564/7303)

| Operations and Tools (1 ha) | Unit Cost (€) | Tot. € |
|---|---|---|
| Hole digging (1×1×1 m) | 6.19 | 619.75 |
| Fertilization per seedling | 0.77 | 77.47 |
| Chestnut (3 years) seedling | 9.75 | 975.00 |
| Stakes | 0.25 | 25.00 |
| Tot. expenditure | | 1697.22 |

* spacing of the trees is 10m per 10m, leading to 100 trees per ha, data refers to 2005.

**Table 6.** Maintenance cost (from La Filiera del castagno laziale, DECOS - Arsial Project 2004; survey with chestnut producers).

| Labor (10.83€/h) | Time (h) | Costs (1 ha) |
|---|---|---|
| Branch pruning (total) | 276 | 2988.00 |
| Pruning charge (per year = 1/6th) | 46 | 498.00 |
| Ground cleaning | 20 | 249.00 |
| Other Activities | 19 | 216.00 |
| Other Costs* | 50 | 541.00 |
| Fruits Picking | 58 | 626.00 |

* Handling: orchard amortization; maintenance; taxes; interest; administration, etc.

The basic input cost is the seedling, €10 per piece, because of sanitation treatment and top quality grafting. Hole digging, instead of ploughing required to avoid destroying mycorrizes constitutes the second bigger cost. In terms of orchard management, picking of fruits is most relevant in those areas where mechanization cannot be applied, followed by overall costs and pruning, every six years.

Other kind of costs concern possible threats to the plants. In Latium there are four main threats, two pests (*Curculio* and *Cydia*) and two virulent fungi (Ink disease – *Phytophthora cambivora* and Chestnut Blight – *Cryphonectria parasitica*) but the most dangerous is *Drycocosmus*, an incoming and devastating insect, which comes from Asia and can destroy both coppices and orchards. It is estimated that suitable treatment for its control will be available only in five or six years from now.

In terms of costs, other pests, and particularly *Curculio elephant*, according to season, require at least one spraying in August. In certain cases it may not be enough as shown in Table 6. It has to be noted that although the cost data reported in Table 7 are not updated, no more than 10% value change has been observed up to day (Dono et al.1999).

A real case study is now analysed, having monitored for four season two chestnut orchards, which can provide an example of what could be the economic results under the best conditions actually achieved. Both farms have most favourable physical conditions, such as to be located on the South-Eastern slope of the Cimini Mountains in Central Italy, on flat ground allowing full mechanized harvesting. The production received biological certification, commanding highest prices, but the two farms differ in the age of trees: the first one is a fairly new plantation, more or less 30 years old, and the second has century old trees. This means that in the former there is still an amortization charge, which in the latter seems absolutely unrealistic to be considered.

**Table 7.** Source: La filiera del Castagno laziale, DECOS, Arsial Project 2004 – Spraying costs per hectare/€

| Type | 1998 | 1999 | 2001* |
|---|---|---|---|
| Worker & Equipment | 33.57 | 34.60 | 73.34 |
| Pest killer Products | 92.96 | 95.54 | 202.73 |
| Total / ha | 126.53 | 130.15 | 276.06 |

* note that the cost is twice as much, because of a double treatment with two different kind of products, due to a bad season for chestnuts.

Total Production amounts to 2.5–2.8 tons at farm price of more than 2000 €/ton, since biologically certified. Variable costs are approximately the same, as well as gross margin, fixed costs, mainly fixed costs (Dono 2000). Costs therefore differ because of amortization charge, still operational in the first orchards and no longer relevant in the second, as before mentioned.

From this fairly representative case of the Cimini mountains around Viterbo it is possible to realize the higly profitable activity relating to chestnut production. It is therefore suitable for an investor to set a chestnut orchard, provided the geo-pedological requirements and the climate conditions would be satisfied. This, however, can not be expanded beyond the physical limits before mentioned. In that district, the limit to chestnut orchards expansion is based also on the competition with hazelnut production, so far more rewarding.

## 4. Results and conclusions

In order to analyze the economic sustainability of the chestnut economy the following critical factors have to be considered.

First of all, the chestnut product, althought at the moment could be fairly rewarding as stated before, needs a strong marketing action to overcome the problem of their seasonality and expanding the sale period. In fact, most of the production is sold in a period of no more than 1 or 2 months (October and November at sharp declining prices after the first two weeks). This is the reason why is important to organize festivals and high food quality campaigns to stimulate interest in traditional dishes and lengthen the consumption period.

The purpose of these strong marketing actions lies on the need to confront decreasing overall prices for the chestnuts and rising labor costs and shortage of manpower for hand picking, which is still needed at large, and determines rather unfavourable results, quite different from those shown in the example.

On the other hand, the farmer who wants to enhance the value of his production should join some certification programme, as PDO, PGI and biological labels, that can upgrade the chestnut products and prices, as the two farms presented above have done.

Another option is to promote aggregate forms of management, because there are production units too small and difficult to manage efficiently. Also, aggregation is one way which helps in adopting mechanical techniques in harvesting. However, chestnut orchards are mostly located in low mountain areas or hills; thus mechanization is highly expensive for a single producer on a much smaller dimension, compared with those of the higly profitable example.

By pooling producers, economies of scale could be generated in the curing process which is highly expensive, according to the traditional technique, but could be industrialized and be fully mechanically integrated on large dimensions of the produce (Dono et al. 1999).

**Table 8.** Tecnichal - Economic average data of the orchards under survey over 4 years (€)

| 1st Orchards | 2003–2006 | 2nd Orchards | 2003–2006 |
|---|---|---|---|
| Gross Total Production | 5359.25 | Gross Total Production | 6006.00 |
| Variable Costs | 893.13 | Variable Costs | 863.13 |
| Gross Margin | 4466.13 | Gross Margin | 5142.88 |
| Fixed costs | 2170.00 | Fixed costs | 601.38 |
| Operational Income | 2296.13 | Operational Income | 4541.50 |

Gross Margin = Gross Total Production- Variable Costs
Variable Costs = payments for inputs, farm laborers, ecc.
Fixed costs = costs relating to fixed inputs
Operational Income = Gross Total Production - management costs, including amortization, interests, taxes and estate fees

Finally, is important to develop new commercial systems; a good opportunity is given by e-commerce, which is slowly gaining ground.

Chestnut is an important product for the Italian rural economy. It could provide a good opportunity to increase farm incomes in marginal areas and opportunities for employment both in the woods and in the local processing industry.

The following issues have a non-positive impact on the market:

- the production structure is mostly based on few regions and single chestnuts orchards are limited in dimension;
- harvesting is expensive and highly labor intensive due to limited mechanization opportunities;
- single producers have poor bargaining power.

To improve the current market situation it is important to organize producers and pool supply by creating added value to the raw material (chestnuts) and gaining economies of scale, by finding and promoting new processed products and, finally, by organizing high food quality campaigns and rejuvenating ancient traditional dishes.

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# Developing and Implementing the Ecosystem Based Multiple Use Forest Management Planning Approach (ETÇAP) in Turkey

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## Abstract

This paper both describes the framework of the ecosystem based multiple use forest management (ETÇAP) approach and its implementation in a case study area. The new management philosophy has four important pillars; the integration of biodiversity conservation into forest management process, characterization and accommodation of multiple forest values, effective participation of stakeholders and use of advanced information technologies and management science techniques. These components are relatively new to forestry in Turkey and calls for a sound framework of forest management planning system as ownership, land use policy, social structure and forest ecosystems are unique to the country. Some experiences from the case study area of Yanlızçam planning unit were documented to realize the performance of the concept. The liaison between the government institutions and major stakeholders is found necessary, and the effective use of Geographic Information System (GIS) and Remote Sensing (RS) have been realized to be critically important. The case study supported the idea that effective participation as communication has better possibilities to promote multiple use forest management than participation as information gathering. Primary challenges relate to the effectiveness of a conservation program, availability of coherent biodiversity data, inadequacy of institutional capacity; awareness, training and common understanding of biodiversity and protected area concept; coordination among the related institutions and stakeholders, and willingness and enthusiasm of authorities to accept and implement the concept.

*Keywords: biodiversity conservation; multiple uses; participation; forest management*

## 1. Introduction

The concept of multiple uses including biodiversity conservation has been a key issue of contemporary forest management (Probst and Crow 1991; Noss 1999; Simberloff 1999; Bunnell and Huggard 1999; Lindenmayer 1999; Baskent et al. 2005a). Despite the long-existing principle of holistic sustainability, there is a continued decline of plant species diversity of forests (Grashof-Bokdam and Geertsema 1998; Fischer et al. 2006; Lindenmayer et al. 2007). The dilemma is that forest and conservation managers need to understand how far society is willing to protect and enhance biodiversity in the context of other investment options (Parviainen and Frank 2003). They also need to compare the relative benefits of investments on biodiversity conservation with those of other investments in sustainable forest management. Such understanding requires insight into how biodiversity is characterized, which forest management practices contribute most to its conservation, interactions between those practices and other objectives (social, economic, environmental), the role of participation and information technology, and what political responses are most likely to result from specified biodiversity conservation practices. The emergence of the concepts of continuous forest, naturalistic, near-natural and ecology-based silvicultural forest management since the 1920s have led to an idea of coupling conservation and management (Baskent and Yolasigmaz 1999; Fabbio et al. 2003). Basically, the ecological, economic and socio-cultural values of forest ecosystems become major components of forest management regulations (Bengtsson et al. 2000; Wulf 2003). Explaining the components will provide the basis for developing a workable framework for resource and conservation managers.

Forest management planning in Turkey is based on a neo-classical approach to satisfy the needs of the society for wood production and services (Asan 1999). Required by law, forest management plans have been prepared periodically with a modified area control method and implemented by the state employed foresters across the country. Influenced by the national forestry program and international conventions on sustainable forest management, biodiversity protection and desertification control, forest management planning approach has changed towards ecosystem oriented multiple use philosophy. In that respect a number of shortcomings were identified in forest management. First of all, management objectives are set to produce solo wood production. Second, a comprehensive forest ecosystem inventory including biodiversity, forest health, capacity, site production and socio-cultural resources has not been conducted to characterize forest values and develop a functional relationship between management actions and forest structure. Third, spatial database has not been built and conservation targets have not beet established under stakeholders' participation for effective management of the forest resources. Finally, forest regulations are generally centralized in addition to incomplete cadastral survey which frequently creates ownership problems during management planning process (Baskent et al. 2005b).

With the support of international projects such as GEF-II (URL-1 2006) and BTC Co. pipeline (URL-2 2006), multiple use forest management planning approach has been developed to overcome most of these shortcomings. The approach is relatively simple focusing on characterization of forest values, stratifying the forest areas for various uses based on a number of criteria and indicators (Bücking 2003; Hagan and Whiteman 2006), setting up forest management objectives and conservation targets with effective participation and finalizing forest management decisions with modeling approach (Pukkala and Miina 1997; Bettinger et al. 1998; Davis et al. 2001; Baskent and Jordan 2002). The process has been accepted by the department of forest management in General Directorate of Forestry in Turkey as a next generation planning approach (Baskent et al. 2005a).

Biodiversity conservation, participation and multiple uses have become the driving force for the new generation forest planning approach (Bengtsson et al. 2000, Eriksson and Hammer

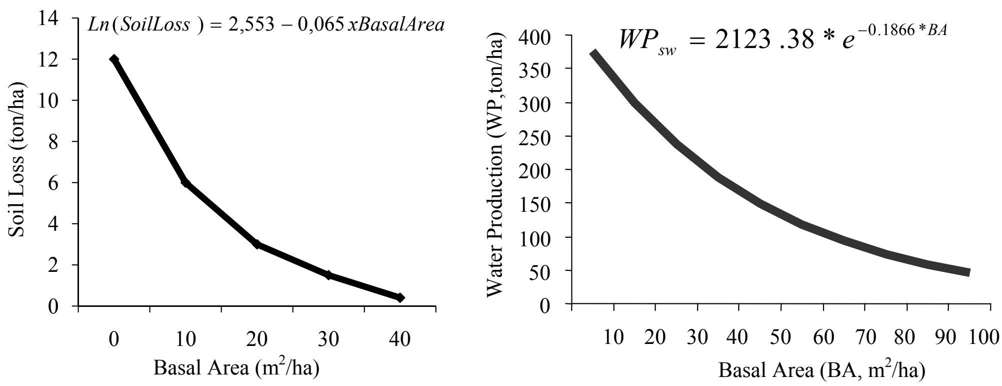


**Figure 1.** The functional relationships between stand structure and forest values for different forest ecosystems.

2006, Schulte et al. 2006). As such, this paper provides conceptual framework of ecosystem based multiple use forest management (ETÇAP) approach, focuses on the basic components and documents its practical implementation in a pilot area of Yanlızçam planning unit. The paper further explains the stratification and participation processes and presents the effective incorporation of biodiversity into forest management plans for sustainable use of forest values.

## 2. Ecosystem Based Forest Management Planning (ETÇAP) Process

ETÇAP concept, first of all, focuses on the integration of biodiversity into the management by characterizing and controlling forest ecosystems to reach demands on a sustainable basis. Various forest values such as wood production, water production, soil prevention, carbon sequestration and recreation potential of ecosystems are inventoried and characterized. After this comes the identification of habitats, usually for focal species which are of special interest in biodiversity conservation (Lambeck 1997). Second, management policies and the related objectives are formulated based on the reflection of owners' demand on forest values and other stakeholders' participation for various uses. Fourth, the functional relationship between the forest structure and the forest values is established to assess the contribution of each forest patch to the management objectives or conservation target. Fifth, a set of alternative treatment actions such as retention harvesting, thinning, planting for each stratified area is prescribed. Finally, appropriate planning or operations research techniques are used to create various planning alternatives to determine the best among them. Based on the various components, ETÇAP focuses on the maintenance of biodiversity, productivity, regeneration capacity, vitality and their potential to satisfy ecological, economic and socio-cultural values without jeopardizing the long term stability of forest ecosystems (Baskent et al. 2008).

In modeling management activities, setting the functional relationship between forest structure and values is paramount. The relationship allows one to forecast the future forest condition necessary to simulate and control the forest structure over time on a sustainable basis. Wood productivity of a site is determined through empirical yield tables of growth and yield models. The amount of soil loss and water production is estimated through basal area using regression models (Figure 1). For example, as the basal area increases the soil loss decreases yet water production increases. The relationship between stand structure and the focal species can likewise be reflected as modeling the habitat preferences of viable population of focal species. Thus, ETÇAP approach focuses on the establishment of such basic relationships then examines alternative management options to meet multiple management objectives.

Decision making tools are central to the design as well as implementation of management plans. While classical approaches utilize typical simulation techniques, ETÇAP uses simulation and mathematical optimization as well as meta-heuristic techniques in developing management strategies and finding the best among them. The concept utilizes monte carlo simulation, linear programming and simulated annealing (to be coded soon) techniques in forecasting future management actions. Spatial features such as opening size, adjacency, accessibility and spatial distribution of patches (i.e., cut blocks, old forests, habitat areas) will soon be part of the model. However, as the concept of modeling approach based on operational research is relatively new to forestry and forest education in the country, it has become quite difficult to implement the decision making tools in forest management planning.

## 3. The case study area: Yanlızçam planning unit

The research was conducted in an area within the very northeastern corner of the country, Yalnızçam of Ardahan Province, to implement and evaluate the success of ETÇAP approach (Figure 2). The area lies in high elevation landscape from 2100 m to 2700 with large pastures in the valleys and forests in the hills and mountains. The total area of Yalnızçam is 44 280 ha, 13% (5885 ha) of it is forested composed primarily of Scotch pine with varying developmental stages and crown closures. Scotch pine (*Pinus sylvestris*) is distributed from the sea level to 2700 m (Ziyarettepe) and it has the largest pure stand formations in Yalnızçam. The area was chosen as a pilot study site for a number of reasons: i) the sub-temperate forests, lying in a biogeographic corridor between the Mediterranean and Central Asia, are within the Caucasian hot spot area that is globally recognized as among the most biologically rich on Earth, ii) the forests are truly unique where Scots pine grows well up to 2700 m in elevation with higher wood quality, iii) welfare of the local population is extremely low creating a pressure on forests resources and iv) BTC (Baku Tbilisi Ceyhan) pipeline passes through the area and provides financial support to carry out various social development and environmental investment projects such as forest habitat enhancement.

There are also some planning problems in the area as well. These include insufficient institutional capacity, ineffective forest protection programs, poor communication with local people and unsustainable use of forest resources due mainly to slow renewal rates and a continuous shrink of forests by fragmentation and degradation. As well, the climate is very harsh with almost six months of winter; infrastructure is insufficient without appropriate water pipelines, sewage system, roads and roofs in houses. The income of the local people is greatly below the average national GDP and their livelihood depends only on animal husbandry and forestry activities.

### 3.1 Major Threats

The forest ecosystems are heavily influenced by over grazing, land conversion to agriculture and rangeland, and cutting of the forest for firewood. On the contrary, the forests are an important natural resource for local communities who graze the areas, clear them for

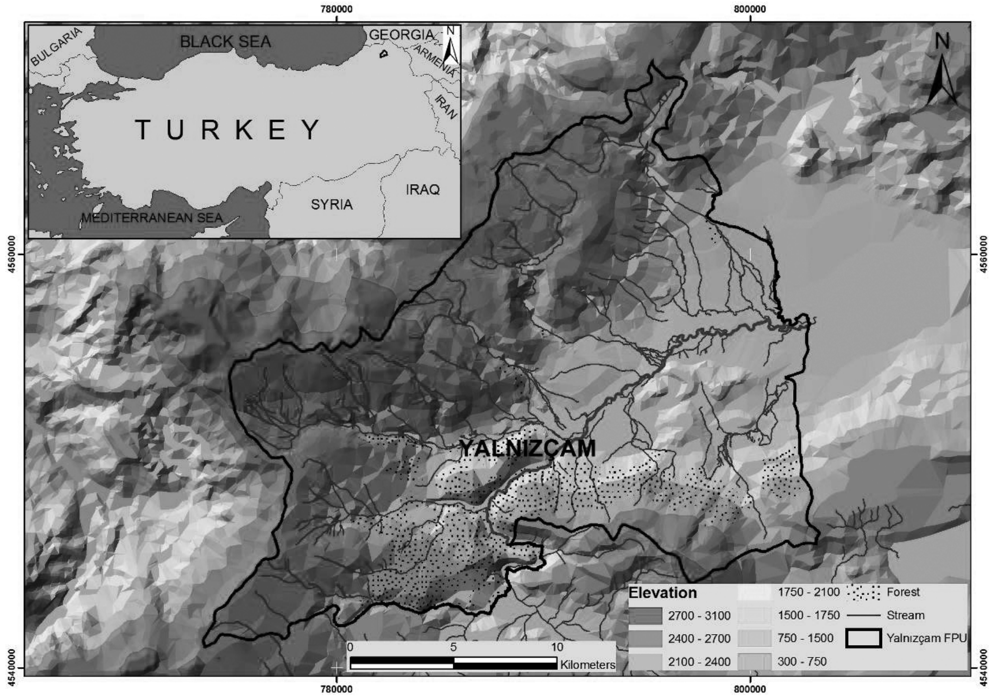


**Figure 2.** The location and the topographic structure of the study area.

agriculture and cut them for firewood. Squeezed by the dilemma, the forests are overexploited, degraded and fragmented generating other problems such as increased soil erosion, deregulation of water resources, and decreasing productivity of grazing and agricultural land. As a result, a cycle of increased rural poverty and natural resources degradation are created to contribute to migration of local people from the region.

Based on the field observations, needs and expectation analysis and a structured regular visit to the area, the following were identified as the major threats to the stability of the forest ecosystems.

1. Lack of sufficient knowledge, information, awareness and interest about the biodiversity and other values of the forest ecosystems among the local communities and stakeholders, even among most of the regional officers working in Ministry of Environment and Forestry (MoEF),
2. Inadequacy of the traditional forest management regulations particularly with regard to conservation of biological diversity, multipurpose utilization of forest resources and participation of stakeholders,
3. Continuous pressure of low-income local communities on forest resources, failure in meeting their essential needs (e.g. fuel.-wood, fodder, etc.) and in earning significant income from forests, inadequacy of rural community development projects, programs and means,
4. Uneven distribution of age classes with accumulation of over mature stands beyond the economical rotation age,

5. Inadequate institutional capacities of the related agencies and stakeholders (e.g. state forestry organization, forest villagers, local NGOs) in the area, poor communication and collaboration rates among them, inadequate budget resources allocated for natural resource management,
6. Habitat degradation, loss and fragmentation due mainly to solo timber oriented forest management practices, uncontrolled and unplanned grazing of livestock, illicit harvesting and fuel-wood utilization of shrubs, hay or fodder production in and nearby forests, poaching, egg collection, fox predation and outdoor activities.

### 3.2 Forest Ecosystem Inventory and Stratification

The planning process started with a comprehensive forest ecosystem inventory process that involved in area, growing stock, increment, biodiversity, site classification and capacity inventories. However, both forest health and economic analyses were not conducted due to financial limitation. Systematic sampling accommodated the design of sample points to conduct the field survey. Circular sample plots of 475 were generated and distributed over the forest with 300 by 300 m grids and located with GPS. Aside from the traditional measurements in each plot such as DBH, height and increment, additional parameters for biodiversity and site classification such as damaged trees, down-dead trees, grazing type and rate, plant succession, plant cover-abundance rate, plant and animal species, woody debris, and soil parameters in a soil profile were measured and/or observed for a comprehensive multiple use planning.

Given the inventory data, Yanlızçam forests were stratified into eight major zones each representing at least a certain forest zone/value (Table 1) and mapped using GIS (Figure 3) with the help of stakeholders' participation. Each forest use was described by a defined number of criteria and indicators followed by the due actions to be applied to each forest use area. The abstract delineation was conducted by the experts and then was discussed with all stakeholders to finalize the stratification.

The stratified areas were used as basis for the management plan. While there were no strictly protected areas almost half (54%) of the areas were allocated primarily for conservation purposes. Biodiversity conservation areas serve as wildlife habitat for four species of vultures and as monitoring the natural development of Scots pine forests. Ecological corridors between pine forests and a coppice forest fragment are used to connect the habitats and allow species to freely move across landscape matrix. The riparian areas allow for the conservation of focal species and provide special habitat for wildlife along the stream bank. Since the forests are generally fragmented, most of the degraded areas and the areas to connect forest fragments are allocated for rehabilitation through aforestation. Both upper forest edges in high mountain areas and lower forest edges near range land are under social pressure by heavy livestock grazing and forage (grass) cutting. Therefore, intensive protection with fences is recommended for these areas when regeneration is prescribed. Aside from the specific allocation of the landscape to each use, landscape matrix and coarse level conservation concept are mimicked to determine harvest levels in the rest of the forest areas by spatially locating harvest areas and determining sustainable harvest amounts.

### 3.3 Building a Spatial Database

The field data in association with the questionnaire for needs and expectation analysis, old cover type maps, aerial photos and satellite images were compiled to create the database with GIS (Arc/Info 8.2). The spatial database consisted of thematic layers such as forest

**Table 1.** Forest zones (values) determined based on criteria-indicators and the associated actions.

| Zones | Criteria-Indicators | Actions |
|---|---|---|
| Aesthetic-Recreation | Natural monuments (earth pillars) along the Kura canyon, traditionally used sites, historical remnants, camping areas, potential ski areas, livestock festival areas, and waterfalls. | Due recreation activities, camping grounds, bird watching stations, no clear cuttings along roads, festival activities, ski routes |
| Ecological corridors | Areas between birch fragments and mass forest areas | Need grazing plan, periodic aforestation with natural trees (pine and birch) light silviculture, no clear-cutting, limited number of dead trees and maintenance of a certain level of growing stock |
| Riparian areas | 200 m around Kura river, 140 m other streams and wetlands, and 100 m around creeks | Light silviculture, no clear-cutting, leave off dead trees, longer rotation periods and maintenance of a certain level of growing stock |
| Rehabilitation | Degraded pine stands, open areas connecting fragmented patches and unsuccessfully regenerated areas | Site preparation and aforestation, fences around regeneration areas |
| High mountain forests | Areas above 2300m elevation, and 70 inside buffer from the upper timber lines | Light silviculture, rehabilitation, panoramic landscape observation, trekking, camping, and ecotourism activities. |
| Biodiversity conservation | IBA, IPA, habitats of focal species, old forests, and stands with big and dead trees | Conservation activities, limited management for wood and leaving out some pine stands to trace the natural developments |
| Social conflict areas | One km buffer around villages, 500 m buffer around other residential areas and 70m buffer inside forest areas from the lower forest line where there is heavy grazing | No management, consensus building among the major stakeholders before the renewal activities in those areas |
| Wood production | Other forest areas | Appropriate amount and level of interventions for quality saw logs and firewood |
| Other areas | residences, agriculture, water and power lines (15 m in both sides) | No management |

cover type maps of 1973, 1999 and 2006, forest stratification maps, residential areas, major land use maps, biodiversity conservation areas, sample plots, disturbance maps, site classification maps, topographic maps (slope, aspect, and DEM), LANDSAT and one meter resolution IKONOS images (August 13, 2005) obtained from the General Directorate of Turkish Forestry. The forest cover type map was updated by interpreting aerial photographs in accordance with high resolution satellite images and rectified with field survey data. The cover type layer included basic information of stand attributes such as species mix, crown

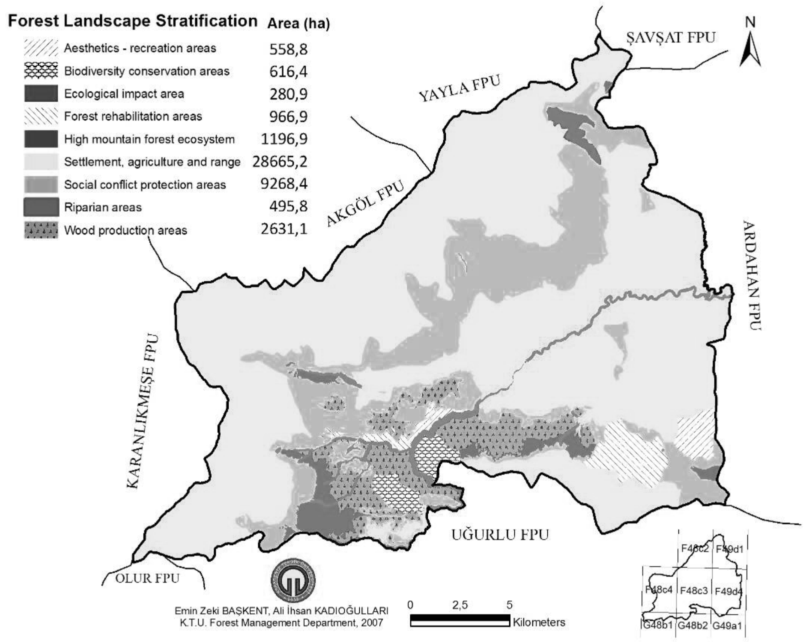


**Figure 3.** The spatial distribution of stratified area.

closure, per ha values of wood and others, land use status, disturbance types and rates, and development and successional stages. The information technologies such as GIS, RS, GPS and database management system were acquired to establish spatial database for developing forest management plans.

### 3.4 Participation

Participation of stakeholders has been a central issue in the development of forest management plans. Participation process promotes effective communication at various levels and generally involves defining the stakeholders, conducting needs and expectation analysis, creating awareness through structured meetings, taking majority decision with democratic discussion, identifying and sharing rights and responsibilities, and finally presenting accountability to the owner (Leskinen 2004; Baskent et al. 2007). The steps were all exercised throughout the process of the research and discussed below.

As a first step, needs and expectation analyses were carried out identifying major problems, threats, target villages and other stakeholders as major players in the management of forest landscape. Under the auspices of BTC and General Directorate of Forestry (GDF), the owner, the stakeholders were grouped into two steering committees. Local steering committee consisted of local government, nine villages, community cooperatives, Erzurum regional directorate of forestry, Ardahan forest and environmental organization, Ardahan agriculture department, rural affairs, KTU, project manager and NGOs of ODOPEM, ORKOOP and International Blue Crescent. The national steering committee embodies department of R&D, KTU, ODTU, project manager, NGOs of ODOPEM, ORKOOP, TEMA and SÜRKAL, and general directorates of natural parks, aforestation-erosion control and rural affairs. The necessary tasks and responsibilities were identified and assigned to each committee. The local committee was charged to be responsible for creating awareness at local level, setting management regulations and discussing local socio-cultural problems with regular visits and meetings. The national committee provides visions, evaluates and supervises the activities to lead the participation process.

The second stage of the participation process was to develop workshops, site visits, town meetings, and questionnaires to create awareness for a stewardship management of forest ecosystems. A first workshop was held to introduce the concept and revise the ecosystem based management planning process to accommodate multiple values, participation and biodiversity into the plans. A community expert was hired to conduct a survey in nine villages for better reflecting their needs. Additionally, a veterinarian and an agriculture engineer were employed to monitor the livestock of nine villages regularly and help design grazing plans and advise for appropriate raising of livestock, respectively. The management team, formed by planning, fauna, flora and database experts, also held a series of town meetings and school meetings to create awareness and discuss the local problems and the outline of the management plans. Also, NGOs were consulted to actively involve them in all meetings. The meetings were managed by an independent facilitator to allow each participant to express his/her views towards any management decisions.

In order to establish a good communication with the local people, create awareness, improve livelihood, reduce fuel-wood consumption and illicit cuttings and thus lessen the potential pressure on forest resources a number of rapid impact or income generating activities were determined and implemented in nine forest villages.

- Restoration of schools, building water pipe lines and drinking troughs in rangeland
- Improvement of rangeland with cultivation of common vetch and clover crops, preparing a grazing plan, sowing animal fodder and making silage with the incentives from the department of agriculture,
- Building a sample greenhouse to produce vegetables such as cucumber and strawberry,
- Implementation of training programs for beekeepers and promoting handmade rags among people in long winter period,
- Training local people for application and development of new community development projects and raising funds from foreign sources (nearly 500000 Euro raised),
- Improvement of a dairy farm managed by a cooperative in a village,
- Roofing buildings with iron sheets and distributing coal burning cook stoves,
- Scanning and spraying animals for good health,
- Training programs for awareness in environment and forestry in group of women, children and adults, and
- Hands-on training of forest workers with modern forestry instruments.

A number of outcomes from the participation process can be noted. First, since the participation was only recently introduced to the stakeholders as a relatively new concept, it took a while to communicate and develop a common understanding, and explain the roles and responsibilities of stakeholders within the management of forests resources. While the traditional state control management of forests (Baskent et al. 2005b) clearly dominated the participation process, the forest management department was fortunately very receptive to stratifying forest areas into both conservation and timber management as necessary. Second, the villagers requested to use the forest areas for grazing and forage cutting whatever the consequence would be. They desired to continue such forest uses as if intrinsically they have the rights to do so. The local committee came up with a consensus to allow limited and planned grazing on the mature-overmature stands where final felling and regeneration is not prescribed. Local people did not initially welcome any restrictions on grazing and forage cuttings in forest ecosystems when habitat enhancement and conservation activities such as setting aside riparian buffers, biodiversity conservation areas, upper-lower forest edges and creating habitat corridors to connect fragmented habitats with aforestation were prescribed. However, after the hectic process of participation and provision of quick impact or income generating activities, the majority of the stakeholders agreed to abide by the necessary management regulations for multiple uses. Third, sporadic grazing in rangelands adjacent to forests and the villages by the outsiders created social instability and conflicts in the area. Explaining the potential impacts in few meetings with the local government yielded a decision to control and stop the outside grazers. There was no apparent influence of community cooperatives on neither forest management activities nor community developments. An expert was hired to train the managers and analyze the status of eight latent cooperatives and it was found out that only four were able to sustain themselves. Some of the quick impact projects such as capacity building and European support for infrastructure were directed towards the enhancements and activation of the cooperatives. Finally, NGOs desired to allocate most of the areas for conservation and to create multilayered old growth type forests, leaving limited use for timber management. A number of special meetings, workshops and educational courses were organized to provide background on the special dynamics of pure Scots pine forest and discuss the issues with officers from forestry department and NGOs. Although all the NGOs were not quite convinced, the potential consequences of the desire were explained and thus even-aged management activities were prescribed to the forests with varying rates and limits depending on the priority of forest uses as depicted in Table 1.

### 3.5 Management Objectives and Conservation Targets

To help set up a conservation target in the area the biodiversity inventory was carried out throughout the year. Both fauna and flora analyses were conducted during all seasons and target species and their habitats were determined together with experts and appropriate stakeholders. Based on the forest inventory data, socio-cultural structure, stratification and biodiversity conservation, management policies were formulated. Management objectives determined under the full participation of stakeholders primarily relate to maximization of wood production. Additionally, resolving social conflicts, utilization of recreation-aesthetic values, and support of community developments activities to increase social welfare with awareness creation about biodiversity conservation were formulated as secondary management objectives. Conservation targets were defined as the restoration of fragmented and degraded forest patches, protection of riparian ecosystems, protection of high mountain forest ecosystems and protection of forest edges under grazing and forage cutting pressure and conservation of biodiversity in the areas.

### 3.6 Management Plan

Under the supervision of stakeholders and the forest management guidelines, a forest management plan was prepared to satisfy both management objectives and conservation targets. The plan did also take necessary planning principles such as international conventions, legal mandates, multiple use planning, spatial database build and interdisciplinary approach into account. The even-aged management system based on both area and volume control was used as the guiding harvest scheduling approach. Varying rotation lengths, from 120 to 180,

**Table 4.** A summary of management decisions in terms of AAC (m³/year) and planting (ha/20 year).

| Management objectives | Rotation period (year) | Final felling (m³) | Commercial Thinning (m³) | Aforestation-Planning (ha) |
|---|---|---|---|---|
| Pine wood production | 120 | 5963 | 2010 | 149.5 |
| Ecosystem rehabilitation | 120 | - | 18 | 482.8 |
| Nature conservation | 180 | 227 | 280 | 62.4 |
| Aesthetic-recreation | 180 | - | 27 | 30.3 |
| Social conflict resolution | 120 | 195 | 82 | 8196.3 |
| Total AAC | | 6385 | 2417 | 8921.3 |

were used in regulating forest dynamics over time and space. The area weighted average site index of 22.34 m indicated site productivity III.

Based on national forest management guidelines and the management objectives the area was divided into five sub-management units (MU) in preparation of silvicultural actions. Table 4 shows the level of planting and Annual Allowable Cut (AAC) decisions based on the first period (20 year) management plan actions in terms of available wood production in all zones. The utilization rate was found to be around 1,2% as compared to 1.7% in regulated forest of solo timber production objective.

The classical area control method was used to regulate forest structure and accomplish a regulated forest structure. Given the rotation age of 120 years the normal periodic area was calculated to be 576.67 ha in pine wood production sub-management unit, the area to be regenerated in each period of 20 years. As the actual structure of the forest was of "old forest" type (areas are generally concentrated to older age classes) there was enough area for regeneration over the planning horizon.

The level and the rate of management actions were determined with a participatory process. Initially, the forest management department objected any "no cut" alternatives in particularly biodiversity conservation and riparian areas due to the specific ecological and silvicultural requirements of pine forests. In contrast, the NGOs always pushed for more areas to be protected, particularly for biodiversity conservation. The contradictory views were ratified by the planning and biodiversity experts again within the participation process as the local steering committee organized frequent meetings and site visits to the area. The outcome was a consensus in majority that harvesting rates in conservation areas could be reduced in varying rates between 10% and 70% as compared to full harvesting on wood production zone. Furthermore, the per area wood production through commercial thinning (~1.7 $m^3$/ha/year) was kept quite far below the average annual increment per ha (~3.4 $m^3$/ha/year) to ensure both sustainability and conservation values.

The success of the implementation of the plan is subject to the resolution of ownership, enhancement of the welfare system of the villages, development of a range management plan and resolution of potential conflicts of dwellers around the forest management planning unit. The agreed stratification of the forest areas is a first step to start the communication with rural people. Then the willingness of forest officers comes into play to coordinate forest management actions with the villagers in line with the management plan. A number of training programs were developed and implemented among the forest rangers to create awareness about the new planning approach used in the management plan.

## 4. Conclusions

Forest management philosophy has changed to accommodate various forest values such as biodiversity, water production, erosion control, recreation and carbon sequestration under stakeholders' participation. Ecosystem based multiple use forest management approach utilizes both fine and coarse filter approaches (mesofilter) (Hunter 2005). Focal species and their habitat requirements provide a clue to the planners. Thus, appropriate set of quantitative measures of biodiversity as proxy is necessary for integration. It is now widely accepted that participatory methods are the most effective approaches to achieve sustainable resource management. Local communities and NGOs are increasingly demanding more say and influence on public forests almost everywhere where forests are public in Turkey. The approach was implemented in Yanlızçam planning unit and certain experiences were realized. Needs and expectation analysis provided basic socio-cultural information, awareness was created among stakeholders, quick impact activities were developed and implemented in villages, ecosystem based multiple use forest management concept has become the prevailing planning approach, both satellite and GIS technologies were heavily used and spatial database built as indispensable infrastructure, criteria and indicators for forest stratification were developed, participation of stakeholders was recognized and the critical role and importance of biodiversity conservation was acknowledged. A shift is required from timber oriented management to the adoption of ecosystem management with new silvicultural treatments and natural disturbances as a template to guide management actions to ensure the conservation and production in balance. Primary challenges relate to the effectiveness of a conservation program, availability of coherent biodiversity data, inadequacy of institutional capacity; awareness, training and common understanding of biodiversity and protected area concept; coordination among the related institutions and stakeholders, and willingness and enthusiasm of authorities to accept and implement the concept.

## Acknowledgements

Funding for the development of this research has been provided by the BTC Pipeline through ORKOOP and ODOPEM in Turkey. The authors would like to thank the staff at Turkish Forest Service particularly the forest management department, the research associates in the Faculty of Forestry, Karadeniz Technical University for providing data and all valuable help.

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# Adaptive Forest Management: Learning by Doing in Forestry

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## Abstract

Adaptive Forest Management allows foresters to face highly variable environmental and social situations. Different emerging concepts (sustainability, both social and environmental change and participation) are challenging traditional forestry around the world. Researchers and foresters share a general interest in developing and applying sustainable forest management. However, it is difficult to find a common meeting point. Through Adaptive Forest Management, we can elaborate a common set of tools to develop and evaluate forest management alternatives. Adaptive Forest Management is a systematic process to steadily improve forestry practices and policies by learning through monitoring and evaluating operational silviculture. Reasons to apply Adaptive Forest Management and difficulties in its application are analysed in this contribution. Science and Forest Management must join forces and take advantage of all the approximations, so that forestry science can help solve real problems for managers in real situations.

*Keywords: sustainable forest management; monitoring; evaluation*

## 1. Introduction

Over the last few decades, an increase in concern about conservation and management of natural resources has been produced throughout the world. This tendency has been reflected in government activities, such as the 1992 Rio de Janeiro Conference. There the general criteria was defined as the need to incorporate Sustainable Management measures for exploiting forests that ensure both rational use of natural resources and persistence over time of environmental values, such as the diversity of species and of ecosystems. This process has had great repercussions at world level, in the 2002 Johannesburg Meeting (also known as RIO+10), and in Europe as well, where there had been several prior meetings and conferences: Strasbourg (1990), Helsinki (1993), Lisbon (1998), Vienna (2003) and Warsaw (2004). In these events, the various countries have reached successive agreements to promote cooperation in forest protection and sustainable forest management (www.minconf.net and www.mcpfe.org). At approximately the same time, other initiatives to try and define appropriate levels and objectives of sustainability have been developed. Thus, the set of criteria and indictors promoted by the Forest Stewardship Council (FSC) exist jointly with many others: the criteria and indicators for the conservation and sustainable handling of the warm and boreal forests (known as the Montreal Process), the criteria and indicators for Amazon forests (within what is known as the Tarapoto Process) and the International Model Forest Network, which includes high-quality management of forests with the goal of defining and developing Sustainable Forest Management at the practical level based on the participation of different social actors.

However, in spite of all these efforts, reasonable doubts exist as to what Sustainable Forest Management is exactly. The different points of view on the subject can be grouped as follows:

1) Traditional practices have been shown to be sustainable – this is certain if we consider the maintenance or increase in forest stocks (volume, surface), and is criticised by those who advocate ecosystem management instead of timber management,
2) appropriate procedures that guarantee sustainability of management practices are needed – these are implemented via principles, criteria and indicators; they are not legally imposed procedures but those having international reference frameworks for carrying out forest policies (Helsinki, Montreal and Tarapoto Processes) in such a way that a set of criteria and indicators for sustainable forest management are available,
3) forest management systems should approach sustainability – the system itself for forest management includes procedures for reaching Sustainable Management, such as the International Organization for Standardization (ISO) Standard 14001, on environmental handling systems, for example,
4) self-regulation by the forest producer or industry – in this case, a set of principles and action lines exist, but there is no external enforcing control; the Paper Industry Association in the U.S.A. has proposed a system of this type, and
5) Follow-up and certification of forest management by a third party – this involves the examination of the systems of forest management and policies (similar to those promoted by the ISO), with ground-level evaluation of procedures and practices and other aspects such as labour safety or the involvement of local communities; it includes the certification of products from forests managed in a sustainable manner (the procedure for FSC certification is an example of this type).

One aspect is crucial for both developing methods and procedures for sustainable forest management and for controlling its execution: adopting adaptive management methods that allow for adapting forest management to the global changes (environmental, social and economic) silviculturists must face at present. The goal of this paper is to present the concept of Adaptive Management, the main forms of its development in forests and its potential in the Mediterranean Basin.

## 2. What is Adaptive Management?

The first publications that presented the idea of Adaptive Management as a useful strategy for natural resource management owe a debt to Holling (1978). As defined by Nyberg (1998), Adaptive Management is a systematic process for continual improvement in management practices and policies through learning from silvicultural activity results. Up to this point, an experienced reader could deduce that you could comply with the idea of Adaptive Management simply through the development of forest handling plans and adequate follow-up, but that is not true. The principal characteristics of Adaptive Management are the following (Nyberg 1998; Stankey et al. 2005):

1. Recognition of the uncertainty about which management practice is "best" for a given situation and/or context.
2. Efforts aimed at integrating knowledge from different disciplines into dynamic models that permit predicting the impact of alternative policies, which requires clarification of problems and improvement of communication between management scientists and other stakeholders.
3. Well-considered selection of the practices and methods to be tested, eliminating options that are improbable or clearly inadequate in the light of the knowledge now available.
4. Careful implementation of an action plan to discover the parts that are critical (given that they are poorly based) in present knowledge.
5. Follow-up on the response of the key indicators to the techniques and practices developed.
6. Analysis of the results in relation to the original objectives.
7. Incorporation of the results into future decisions.

What is involved is a process in which each management action (clearing, thinning, pruning, planting, etc.) has to be considered as part of a real-life-scale experiment that must be planned to obtain useful information, so as to orient future forest management. Adaptive Management therefore has to do with overcoming the concepts of permanent plots, tests of origin or experimental sites and complementing them – or replacing them – with these life-sized 'experiments'. So it is a case of learning-by-doing, of taking advantage of successes and failures, both one's own and of others.

However, although the learning-by-doing concept is essential in the application of Adaptive Management, for it to be really useful there should not be only one incremental dimension of knowledge. There must be a formal, explicit and deliberate process for increasing useful manager knowledge through experiments and contrast, critical result processing and the application of new management strategies (Stankey et al. 2005). Lastly, for the learning to be real and for it to have a clear impact, it must have two dimensions: a cognitive one (we understand processes we have studied better) and a behavioural one (we change our way of handling forest management).

## 3. Adaptive Management foundations

The basis of Adaptive Management is that the management must start from life-sized 'experiments' based on our scientific knowledge. That way the underlying hypotheses can be tested and the validity of the predictions can be checked, so as to improve our management with the results obtained. The core idea is that management of the natural environment should be technical, but with an anthropological and ecological basis. Management development will therefore be scientifically admissible, technically possible, economically viable and socially acceptable (Bravo 1989).

### 3.1 What are the main reasons for developing an Adaptive Management programme?

The main reason for implementing an Adaptive Management programme is that, by doing so, we are converting a local experience – of no value for determining cause-effect processes – into information useful in analysing the 'whys' of the results obtained. We can thus raise the level of technical knowledge applied to forest management. To apply management techniques such as those called pastoral "routines", a scientific or technical basis is not necessary; the only thing needed is a person skilled in repeating what has already been done before. If environmental, social or economic situations do not change, applying good "routines" is very effective. Certainly, under those circumstances, society will not ask more of the foresters. However, in a highly changeable situation (climate changes, changes in social preferences with respect to forests, changes in productive uses, etc.), the scientific knowledge we can obtain from Adaptive Management is indispensable in responding to society's needs.

Of course, factors related to snobbism and a good image associated with innovation could also be argued. However, if these are the principal reasons, we will not get very far wasting valuable resources on lovely image campaigns.

### 3.2 What are the main difficulties in developing an Adaptive Management programme?

The main difficulties in implementing an Adaptive Management programme depend to a great extent on local conditions, but they are generally the following:

1. Excessive bureaucracy of public administration towards forest managers.
2. Lack of means and techniques know how of forest management in private lands.
3. Lack of training in advanced statistical techniques (experiment design, Bayesian techniques, etc.) and in methods of making decisions under uncertain conditions.
4. Lack of knowledge of Adaptive Management methods and techniques.
5. Lack of systematic doubts in the application of management procedures In Engineering Schools, students are rarely taught to doubt; doubt constitutes the engine that drives technical advances.
6. Managers do not have a tradition of exchanging experiences among themselves and with the scientific community.

Budget restrictions do not usually constitute a problem, given that costs are limited if Adaptive Management criteria and procedures are introduced in management design.

### 3.3 Why doesn't the transfer of information from scientists to managers work?

A great deal of effort is expended on research, development and innovation in all spheres, including those related to forest ecosystem management. Nevertheless, there is no adequate channel that allows researchers to communicate their results effectively with managers or that lets managers promote the research that responds to their needs. On the other hand, the scientific system promotes and rewards extending results among other researchers through publishing them in specialised journals. However, these journals are often difficult for managers to access, because they are only available through university libraries or research centres. In addition, managers find it difficult to have sufficient economic resources and time available to attend specialist congresses. According to Finch and Patton-Mallory (1993), there are other factors that must be taken into consideration in explaining difficulties of transferring information between researchers and managers:

1. Research results are normally dispersed and appear in fragments in several publications. There is a lack of publications that synthesise all the information in a set of management recommendations.
2. There are no adequate processes to identify and prioritise the knowledge gaps in a way that allows research results to become part of the state of the art.
3. Part of the information generated by researchers has only limited usefulness because it centres on overly-specific aspects.
4. Work routines and environments generate philosophical barriers between managers and researchers. The researcher normally carries out his or her work with greater liberty, while the manager has to deal with political and economic realities in day-to-day decision-making.

## 4. Fundamental methods for data analysis within an Adaptive Management programme

An Adaptive Management programme requires the managers and researchers to work together from the start of planning the actions from which extracting scientific knowledge is desired (Finch and Patton-Mallory 1993). Managers will be more willing to use the new knowledge generated if they feel part of its generation from the beginning. Likewise, researchers will provide their capabilities more usefully if they are involved in forest management planning from the very first. In addition, the information must be shared systematically for it to be possible to explore aspects that were perhaps not foreseen in the initial plan, but can later turn out to be of great interest. Lastly, the organisations must prioritise the research, follow-up and management in such a way that the individuals responsible for these activities and the supervisors of managers and researchers effectively evaluate and reward the activities.

### Data Analysis

The first step is to decide if we want to do a retrospective study or a prospective study applicable for the development of Adaptive Management. If it is assumed that our interest lies in knowing the effects of fire on the forest, we can focus on the problem in two ways:

(1) Look for already burnt areas and choose some of them for the study, comparing them with others selected as the control. An example of this is the recent project by Núñez (2006), and (2) choose an area and wait until it burns or burn it under control to carry out the study. The first option is a retrospective study, while the second is a prospective study.

Both models are useful in obtaining valid conclusions for Adaptive Management (Smith, 1998). However, the lack of control over some key factors in the burnt and control areas in the retrospective study make it necessary to take additional precautions in result analysis and interpretation when using this model. In many cases, Adaptive Management should be based – at least during the first stage – on only retrospective studies. This limits the validity of the results, which should be taken as a first approximation.

**Tools**

Every Adaptive Management programme should be based on the following tools to obtain a set of reliable data from which well-founded conclusions can be drawn:

1. Long-term experimental sites with sophisticated experimental devices. In Spain, there is no experimental site comparable to those integrated in the Long-Term Ecosystem Research Network (LTERN) in the United States. This network provides a theoretical basis for adaptive management activities. The problem with long-term experimental sites is that, as they get older, their value increases, but it is also probable that the scientific question that motivated their initiation has lost relevance (Innes, 2005).
2. Monitoring plot networks. These plots can be temporary, interim or permanent, based on the number of remeasurements that have been performed. An adequate balance between all the plot types distributed for all the silvicultural situations of interest is crucial for extending the results in long-term intensive experimental sites. The problems involved in designing Monitoring plot networks and in their follow-up have been compiled by Curtis and Marshall (2005). They pointed out that, in many cases, plot documentation is inadequate, plots are too small and/or installed without buffer areas, applicable treatments have not been assigned randomly, tree measurements are not adequate (in number, in tally-tree selection, etc.), age estimation is imprecise, conditions prior to treatment have not been registered and a long etcetera. However, when Monitoring plot networks exist, they constitute a key element in increasing forest management knowledge.
3. Regional analysis. Isolated results of 'tests' that managers can carry out in each site are of scant value. There must be a plan for the management alternatives to be tested, at least at the district level, so that valid conclusions can be drawn. If this is not done, money will be wasted in local 'tests' of absolutely no value, as we cannot distinguish the results that show arbitrary relationships from those that show causal relationships.
4. Modelling and simulation. It is not possible to test all the options, but adequate models allow them to be simulated and conclusions drawn. This will, at the least, eliminate the options that are clearly undesirable and establish a clear hierarchy among the different management alternatives. An example is the work of Bravo et al. (2008) from the simulation of two management alternatives (short and long rotation) in stands of two species (*Pinus sylvestris* and *Pinus pinaster*) in the north of Spain that represented two productivity levels (high and low site index). These researchers could determine the impact of the alternatives simulated on carbon storage in the forests; in addition, by including the analysis of different carbon prices and different discount rates, they could study the impact of establishing payments for carbon storage credits in the forests.
5. Integration of results at multiple scales. Forests are holistic systems, in which the whole is more than the sum of the parts. The bottom-top approach to problems (from the tree to the landscape) must be complemented with a top-bottom approach (from landscape to tree), in such a way that a vision of the unit, absent if we observe only one level, can be obtained.
6. Harvest analysis (Gadow and Kleinn, 2005). This involves selecting areas where cutting is going to be carried out (clearing or regeneration cutting) and measuring all the trees once the cutting is marked. After the cutting is performed, we will have information available on the stand before and after cutting and on the cutting itself. Analysis performed after a pre-specified period of time, from a network of such sites, could give us valuable information about forestry practices at a life-sized scale. Of course, such analysis does not have to be restricted exclusively to clearing and final cutting. It can be extended to other forestry activities.

## 5. Model forests as a framework to develop Adaptative Management

As foresters face uncertainty both at the environmental and economic level, they need to develop forest management strategies in fuzzy situations. Adaptive management allows foresters learn by doing practical forestry while developing sustainable forest management. In places where a lack of scientific knowledge exists, as in some parts of the Mediterranean basin, implementing these learning by doing strategies can help managers to design adequate strategies to achieve sustainability and to increase forestry knowledge.

Model forest is a concept based on a combination on social, cultural and economic needs of local communities on forest areas where sustainability has been applied in practice for a long term. In the model forests both public and private organizations sharing a common objective cooperate to achieve and develop sustainable forest management in a given local forest area. The principles which the forest model concept relies on are: partnership, sustainability, management at landscape level, good governance practices, knowledge-sharing and networking. A model forest currently exists in the Mediterranean Basin, in the region of Castilla y León (northern Spain). This model forest is called "Urbión". It includes the mountain pine forests of the Urbión mountain range (in northern Spain), pine forests of wild pine (*Pinus sylvestris* L.) being the dominant forest type. Additional information about this model forest can be found at the website www.urbion.es. The Urbión forest model has a long-standing tradition on sustainable forest management. The first management plans date back to the 19th century and since then sustainability has been the main forest management objective. First a sustainable yield approach was applied but during the last decades management objectives have shifted to a comprehensive approach including non-timber values, biodiversity conservation and carbon sequestration, jointly with timber production, as main outcomes.

## 6. Conclusions

Forest management is carried out in a changing world, from the economic, social and environmental points of view. It requires management methods that go far beyond traditional "routines", as has been indicated earlier. Investment in forest research can be especially difficult in countries where other priorities may need the economic support available with a greater urgency (such as those in the south and east of the Mediterranean Basin). That is why it is important for all the data that can be obtained from forest management activities to be integrated in formal processes in order to increase directly applicable scientific knowledge. Initiatives such as implanting model forests can help to structure and implement this kind of initiatives.

To make all these efforts related to Adaptive Forest Management (model forests, learning-by-doing, etc.) truly useful, researchers should come out of their own circles and their laboratories and test networks to approach the managers. Managers, in turn, have to change their mentality and stop considering scientific activities a madness involving theoreticians and naïve people that have little use except for adding a certain image of modernity. Society needs technical decisions based on knowledge and in constant adaptation to changing situations. Science and forest management cannot follow parallel paths, much less opposite paths. All the efforts and the approximations have to be utilised wisely, so that forest management regains its scientific basis and forest science can help to solve real problems of managers in real situations.

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# Contribution to the Sylvester Mushroom Inventory and Estimation of the Production on Permanent Plots in Kroumirie, Tunisia

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## Abstract

The Kroumirie is the most irrigated region in Tunisia and its climatic and edaphic factors are favourable to mushroom multiplication. Field studies showed a very large potentiality in the region. Inventory of fungi potential permitted the identification of the following big families: *Agaricaceae* (*Agaricus arvensis* and *Agaricus campester*), *Cantharellaceae* (*Cantharellus cibarius, Craterellus cornucopioides*), Boletus or tube mushrooms (*Boletus chrysenteron*), *Clavariaceae* (*Ramaria botrytis*), *Lepiotaceae* (*Lepiote procera*) and *Russulaceae* (*Russula vesca*) and *Lactarius delicious*.

After this first survey we identified the main species of the region and showed the value of this important potential badly used and unknown by the local population; especially when it presents an important economic and nutritive value.

*Keywords: inventory; sylvester mushroom; Kroumirie, Tunisia*

## Introduction

Mushrooms are organisms related to plants, but are distinguished, in particular, by their non-photosynthetic nutrition mode (Lanier 1978). They constitute a distinct numerous and varied group, living apart from the animal and plant reign.

Mushrooms are aerobic organisms. They are very rich in water. Their development requires a lot of water and oxygen but also an organic carbon source because they cannot carry out the photosynthesis.

EFI Proceedings No. 57, 2009
Modelling, Valuing and Managing Mediterranean Forest Ecosystems for Non-Timber Goods and Services
Marc Palahí, Yves Birot, Felipe Bravo and Elena Gorriz (eds.)

In nature, they are in presence of polysaccharides that they must first degrade before absorbing them. They secrete the digestive enzymes that degrade these complex sugars into simple ones. They need mineral nitrogen to synthesize new nitrogenous molecules such as amino acids.

Most mushrooms' reproduction is assured by the billions of spores that they produce.

Among this large number of mushroom species met in the world, about 150 are edible, but only about twenty species that deserve the honours of the kitchen still remain (Becker 1982). This potential remains unknown in the Kroumirie region. This is the first study in this subject. Mushrooms have been collected only in the last few years; it was not known even by the population. In the present work, we try to inventory the majority of edible species met in this zone and to estimate their production. With this paper, we hope to explain the importance of the main species for consumers, especially that they have a very high nutritive value.

## 1. Material and methods

### 1.1 Study area

The survey zone is the Kroumirie. It is a region where we can find natural mushrooms or Sylvester ones. This region presents large varied forests which are the most watered of Tunisia.

The Kroumirie is bio-climatically the most privileged region of Tunisia (Emberger 1938, 1942, 1954); its largest part belongs to the humid bioclimatic level.

We note an increasing rainfall gradient from East to West (from Bizerte toward Tabarka) and from sea level to altitude (from Tabarka toward Aïn Draham), so Tabarka is included in the lower humid bio-climate while Aïn Draham, Aïn Zena and El Feidja are located in the humid high one.

Altitude rainfall gradient is in the order of 75.5 mm/100 m (Dimanche and Schoenenberger 1970). According to this fact, valleys appear distinctly drier than reliefs.

Precipitations are more than 600 mm/year everywhere. They are more than 1500 mm in Aïn Draham (very windy passageway and particularly watered) at 720 m of altitude; they are on an average of 1000 mm/year in Tabarka on the North coast and only 600 mm/year in Fernana, about thirty Kilometres to the south of Ain Draham and at only 400 m of altitude. These variations, in relation with the altitude, allow us to suppose that precipitations can be higher in greater altitudes and can reach 2000 mm/year in Djebel El Ghorra (1203 m) (Hasnaoui 1992).

The seasonal rainfall distribution shows that 45% of the rainfall is annually concentrated on the three winter months, whereas only 3% fall in the summer season (Kassab 1979 and Henia 1980).

The average temperatures of the coldest month are the following: Tabarka: 11.1°C, Aïn Draham: 6.6 °C and El Feidja: 6.2°C. The absolute minimum temperatures are - 1°C in Tabarka, - 5°C in Aïn Draham and - 6.5°C in El Feidja, all are recorded in January). The average annual temperature decreases with the altitude 17.9°C in Tabarka on the coast, 14.9°C in Aïn Draham at 720 m of altitude and 14.3 in El Feidja at 900 m above sea level (Hasnaoui 1992).

Relative air humidity is very high during the period from October to February (85% in January), less so in August (60%), and very often, throughout the year (Ben Tiba 1980).

### 1.2 Methodology

Plots choice was done according to the ecological features (dominant species) and orographic factors (altitude, slope, and exposition). In these different surroundings, we cleared two strata according to their altitude:

- The first one less than 300 meters;
- The second one more than 300 meters.

In every identified stratum, we cleared under-strata according to dominant species: Pine (*Pinus pinaster* or *Pinus pinea*), cork oak (*Quercus suber*), zeen oak (*Quercus canariensis*), shrubs (range in height from 0.3 to 5 m) and non-cultivated land. We fixed five permanent plots of a quarter of hectare in each under-strata and selected lots of 22.7 m equivalent to an area of 1619 m². The total of plots was fifty (5 plots × 5 under strata {Pine, cork oak, zeen oak, shrubs and non cultivated land} × 2 strata [The first one less than 300 meters and the second one more than 300 meters]).

No special intervention was made been made in any of the plots. We just followed the natural conditions. We followed a passage every fifteen days from the beginning of November till the end of February, in view to identify, inventory and estimate the different edible mushroom species. To collect mushrooms, we used a sharp knife to cut the over part and leave the roots in place. Collected species of each plot were weighted in the laboratory. This study took four years.

The production was not regular. Some species did not appear during two years which is why we did not apply any statistical test. We merely took the mean production range for each mushroom species.

The morphological description of the different species has been verified on the BORDAS guide.

## 2. Results

### 2.1 The *Agaricaceae*

This very particular family includes two important kinds under our moderate climates. Agaric kinds include very numerous species. At these mushrooms, gills are free and the veil generally well developed forming a ring.

*Agaricus arvensis* (Fallows Agaric): It is an edible and delicious species, generally big and chunky, with white hat strap on yellow, its ring is formed by two distinct layers around the foot. It grows in grasslands. This species has been harvested under different surroundings (pines, cork-oak, non cultivated lands).

*Agaricus campester*: It is a good enough edible species, with pale hat of 4 to 10 cm diameter, rose blades which become black, fusiform stipe with a fleeting veil.

These two species are invariant to altitude (less than 100 m and more than 500 m) and grow in sloped and flat terrains (10 to 25%). They are generally collected from the end of November after the first big rains. They grow spontaneously on non-cultivated lands and brown forest soils.

### 2.2 The *Cantharellaceae*

These mushrooms form an intermediate group between gill mushrooms, very evolved, and the most primitive group. These species include a foot and a funnel-shaped hat. The fertile surface, lower face of the hat, is sometimes smooth but can be creased more or less. Most species have good edibility but some are not good enough.

*Cantharellus cibarius* (Chanterelle): Chanterelles are good enough edible species, with a hat of 3 to 10 cm diameter, thick and fleshy, flat or a little depressed in cuttings, matt and dry, their gills are not the thin strait slices that we are used to seeing under the hat of mushrooms.

They grow on clayey soil, under cork-oak trees and dense shrubs whose plant litter is well decomposed.

*Craterellus cornucopioides* (Death Trumpet – Abundance Horn): This is a species with a good enough edibility, having a blackish grey colour. It has a trumpet shape. It can have 10 cm height and 7 cm diameter. Its flesh is very thin and brittle. It grows on clayey and calcareous clay soils under cork-oak close to streams.

These two species have a preference to heights (more than 400 m). They are invariant to slopes and grow naturally on fresh expositions (North).

They are often harvested from November after autumn first rains.

### 2.3 The *Boletus*

Boletuses exist all over the world, under moderate and tropical climates. Of the entire hat mushrooms set they are, probably, the more curiously colourful, the most voluminous and most delicious to consume. In some species the hat reaches a diameter of 60 cm on a very massive foot, while other species hardly measure few centimetres. Nearly all are characterized by a tender and fleshy structure. These tubes are closely tightened against each other under the hat and their opening is known as a pore, the only visible part of the tube if it does not break or cut the hat. Flesh colour variations are extremely common in this family and are often very useful to identify species. Nearly all boletus are considered edible; rare are those that are a little bitter. One of their species is the Cep (*Boletus edulis*), one of the most famous among the edible mushrooms all over the world.

*Boletus chrysenteron* (Yellow Flesh Boletus): It is a medium edible species, but little tasty, with a hat of 4 to 12 cm diameter. It grows on evolved fairly deep to heavy texture soil, under cork-oak and scrub.

*Suillus granulatus* (Granulated Boletus) – pines yellow Cep: It is a good enough edible species, its hat is 6 to 12 cm of diameter. It grows on brown forest soil with heavy texture in presence of hydromorphy, under cork-oak in abundance of a little evolved scrub.

*Boletus edulis* (Bordeaux Cep - Edible Cep - Edible Boletus -Thick Foot)

It is a good enough edible species, its hat is 2 to 20 cm of diameter. It grows on brown forest soil with heavy texture in presence of hydromorphy, under cork-oak and well developed scrub whose plant litter basis is little decomposed humus.

These three species of Boletus have a preference for altitude zones, with light slopes (less than10%), with South exposition. They are harvested from November onwards.

### 2.4 The *Clavariaceae*

These species are mainly basidiomycetes, typically fleshy or in more or less small shrub branched, sometimes with a thick fleshy base. Nearly all their surface is fertile, sometimes a sterile base more or less developed. However, some ascomycetes with very similar shape were also placed in this morphological group.

*Ramaria botrytis* (Ramaire Cauliflower)*:* It is an edible species, very branched, with very thick base, whitish cream to pale beige, pink extremities, thick flesh, massive foot branching out in shape of corolla head, 5 to 20 cm in diameter. It grows under broadleaved trees and sometimes coniferous species. This species is harvested from December, on high altitude places and even on strong slope sites.

## 2.5 *Lepiotaceae*

The parasol mushroom kind in the strictly articulated sense have several groups, according to the spore shape and microchemist behaviour.

This family's characters are: appendicularians margin, no streaks, free blades, fine bone and white flesh.

*Lepiote procera* (Elevated Parasol Mushroom): It is a good enough edible species, with a hat of 10 to 30 cm of diameter, first spherical then ovoid, tight white blades, very big foot reaching 30 cm, with a very fragile necklace.

It grows on clayey soil little evolved with light texture, under cork-oak and zeen oak.

*Macrolepita rhacodes*: It is a species with a medium edibility having a conical hat of 15 to 18 cm in diameter. Free white and tight pot-bellied blades, the foot with a necklace.

It grows on brown forest soil rich in humus and under pines.

These two species are invariant to altitude, slope and have preferences to fresh expositions (North) and in the old charcoal locations. We harvested them from November.

## 2.6 The *Rusullaceae*

*Rusullaceae* are remarkably homogeneous, having a flesh with a brittle granular texture. Lacteal and rusulla are very easy kinds to recognize (in the field, stipe breaks like a piece of chalk, without making filaments or fibres). The lacteal have long blades which are not fixed on the habitual common point and a depressed hat. *Rusulla* are chunkier, with a little dogged hat. *Rusulla* and *Lacteal* form mycorhizes with various trees.

Their constant characters are: convex hat either spread out then depressed (especially for lacteal). Their flesh is granular, heterogeneous, made by a mixture of round and long cells usually containing latex. After breakage these species exude colourful milk.

*Russula vesca* (Edible Rusulla): It is a good edible species. The upper hat is 8 cm in diameter, with white colour gill and foot. It grows on clayey to hydromorphic soil, under cork and zeen oak.

*Lactarius delicious* (Lacteal Delicious): It is a species with a medium edibility, its hat is 8 to 15 cm in diameter, with orange colour, orange gill, white foot speckled with orange colour.

It grows on non-evolved to heavy soil texture with light hydromorphy and under pines.

These two species are invariant to altitude, but are very frequent between 400 and 700 m, in north exposition. We inventoried these species from the end of November.

## 2.7 The Production Estimation

The inventory of sylvester mushrooms in the Kroumirie zone showed a very varied potential. The evaluation of the production for the majority of species gave the following results:

- Chanterelle: 0.5 to 1 kg/ha ;
- Lacteal delicious : 8 to 15 kg/ha;
- Pin cep: 1 to 1.5 kg/ha;
- Fallows agaric : 0.5 to 1 kg/ha.

The assessment of the production is very variable and bound to the climatic conditions; that is why fluctuations are often very important.

## 3. Discussion

The distribution of sylvester mushrooms is significantly related to the climatic, orographic and edaphic conditions. Species appear spontaneously when the humidity is near 100%, the lower temperature 25 °C, and the soil slightly acidic. These results are confirmed by Kranabetter (2002): Soils were well to very rapidly drained and generally coarse in texture, often with a high coarse fragment content and thin forest floor.

The majority of mushrooms are in the medium altitudes between 400 and 700 m and in fresh exposition (North).

Usually, *Lactarius delicious* are collected earlier than the others. Their starting time depends on the quantity of rain. It happens that we do not get heavy rains till the beginning of December and in some years some species do not appear at all.

These conditions determine fruiting period of different species and explain their time of appearance from a region to another.

Numerous factors influence fruiting of mushrooms such as rainfall and temperature (Hosford and Ohara 1995), and other biotic and abiotic factors (Ohara 1994). Mushroom species differ essentially by vegetation (broadleaf trees and resinous ones). Some are invariant to vegetation types (mixed forests and uncultivated areas).

Typically types of mushrooms are associated with specific trees and substrates (Amaranthus et al. 2000). The association between mushrooms and their mycorrhizal host frequently varies by geographic location. Fruiting is non-uniform. The spatial and temporal variability in fruiting and insufficient ecological knowledge of the mycorrhizal mycelium has challenged research and monitoring efforts.

## 4. Conclusions

The region of Kroumirie is a very suitable area for sylvester mushrooms according to floristic, edaphic and climatic diversity.

The Tunisian consumer is not informed on this subject, as most of the edible species are not known. This potential remains poorly exploited.

Most mushrooms are constituted more or less of edible or poisonous species. Indeed, many mushrooms well-known to be edible species can provoke various concerns for some people. Mushrooms are not only made to be eaten. Their roles in nature are varied and extremely important. They are fundamental agents of the biological balances. They are also scavengers, regulating populations and auxiliary of plants.

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# The Role of Medicinal Plants in Oak Forests in Idleb, North-West Syria, in Improving Incomes of the Rural Poor

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## Abstract

The biodiversity in the oak forest in Idleb Province, North-west Syria were exposed many years ago to degradation caused by over grazing, cutting wood, rock and stone removal, cultivation, quarrying and terracing for planting fruit trees and field crops.

All plants are important and essential to life, and the rural poor depend on plants for their survival, food, medicines, clothing, shelter and fuel.

So actions that are necessary include limited human impact on the biosphere, maintaining biological wealth, promoting technologies, developing a clear policy for protection, production, transportation and marketing of medicinal plant raw materials that are sensitive to the needs of the rural poor who depend on natural resources for income and establishing extension programs on the conservation and importance of medicinal plants that increase benefits to help the rural poor.

*Keywords: degradation of biodiversity; medicinal plants; improving incomes of the rural poor.*

## Introduction

The biodiversity in Al-Zawia and Al-Wastani Mountains in Idleb Province were exposed to degradation year after a year and the vegetation cover decreased the cultivation was applied even between two rocks and planting spaces less than 5 $m^2$.

So the Government of Syria, through the Ministry of Agriculture and Agrarian Reform (MAAR), requested IFAD to finance an agriculture development project, and the project needs to undertake, among others, eco-geographical and botanical survey in order to ensure that areas with valuable plant biodiversity are developed.

**Table 1.** Latitude, longitude and altitude of Al-Zawia sites.

| | Kafar Lata | Kafar Haya | Al-Rame | Dar-Dobat (Al-Bara) | Mohanbel | Kokfeen | Bab-Alah |
|---|---|---|---|---|---|---|---|
| Latitude | 35.79077 | 35.74908 | 35.75354 | 35.68062 | 35.79022 | 35.63431 | 35.83680 |
| Longitude | 36.61841 | 36.59850 | 36.53848 | 36.52614 | 36.48305 | 36.41740 | 36.52752 |
| Altitude | 801 | 781 | 671 | 732 | 526 | 662 | 471 |

**Table 2.** Latitude, longitude and altitude of Al-Wastani sites.

| | Oreba | Al-Fasook | Maryameen | Al-Daher |
|---|---|---|---|---|
| Latitude | 36.14626 | 36.01392 | 35.91133 | 35.95978 |
| Longitude | 36.50709 | 36.45195 | 36.40605 | 36.41823 |
| Altitude | 457 | 531 | 479 | 326 |

Attitudes toward development that are based on conservation are a move to redress the balance between the plants, which have a right to exist, and the future generations of people have a right to expect adequate resources and thinking about the economic benefits of people derive from plants (food, feed, medicine, resins, fuel, oil, industry...etc),

## Objectives

- Map the botanical biodiversity (I think that it's more relevant to say botanical diversity or plant diversity) within the project area, particularly in relation to the occurrence of indigenous wild species and land species.
- Assess economic importance of the botanical biodiversity identified in the project area.
- Conservation of the biodiversity by encouraging farming practices that are compatible with good management of the natural resources.
- Rural development is a frequently stated purpose of aid programs, the overall goals being to ameliorate poverty, unemployment, poor health and inequality.

## Methodology

- Selection of the Monitoring Area: the selection was conducted during March 2007 by a team in Al-Zawia and Al-Wastani Mountains and the selection of monitoring areas was based on the following criteria:

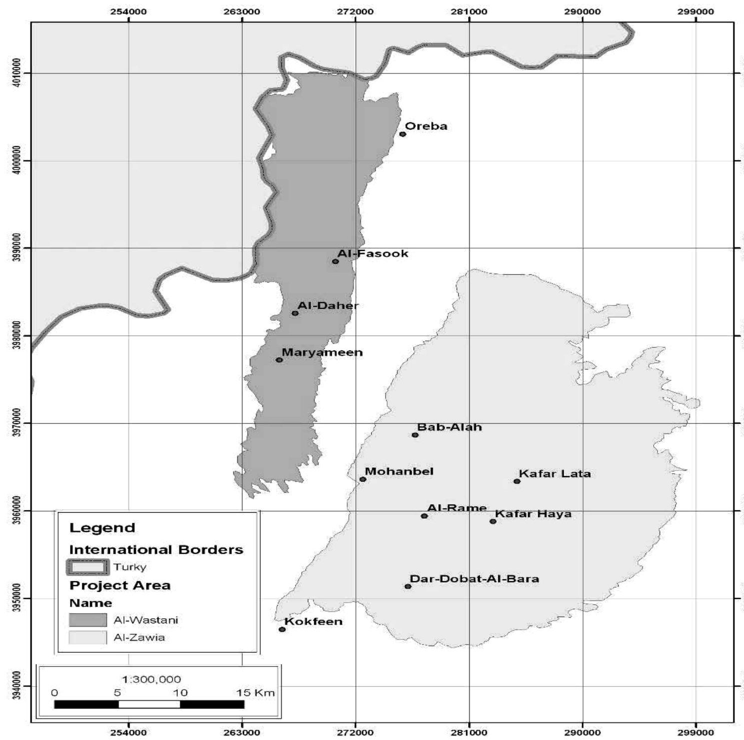


**Figure 1.** Map of the project area of Idleb shows the monitoring areas in Al-Zawia and Al-Wastani Mountain.

1. Covered different land use.
2. Covered different parent rocks: (e.g. Basalt, light limestone, dark limestone).
3. Covered a protected area and a degraded area.
4. Covered a different plant community.
5. Covered a wild herbaceous area and a forest area.
6. Covered a natural area and a cultivated area.

- Duration of Botanical Survey: From mid April up to mid-June 2007
- Levels of Survey: the surveys were at three levels:

1. The project area levels: 2 levels: Al-Zawia and Al-Wastani Mountains
2. The monitoring area levels: 7 monitoring areas were selected in Al-Zawia and 4 monitoring areas in Al-Wastani. Tables 1 and 2 show the sites names and coordinates, Figure 1 shows the monitoring areas in Al-Zawia and Al-Wastani Mountains:
3. The transect area levels: 3 levels of transect for each monitoring area for both herbaceous and tree plots.The length of each transect was (50–250m).
4. The plot area levels: 5 plots were selected in each transect of each monitoring area for both herbaceous and tree area The distance between plotswas (15–30m), plot size in the herbaceous study was 1 $m^2$, while the plot size in the tree study was 100 $m^2$.

## Measurements

- Coordinates: Latitude, longitude and altitude were recorded in the middle of each monitoring level and each starting and ending point of the transect level and each plot level.
- Photography: Photos were shot in each monitoring level and each transects level and each plot level.
- Terrain: Slope%, slope aspect and slope length were measured in each transect and slop aspect in each plot.
- Soil: in each plot the following characters were measured:
  - Depth (cm),
  - Color (reddish, brownish, yellowish, grey or black),
  - Texture (Clayey, loamy, sandy or organic), Moisture (dry, moist or wet),
  - Aggregates and plough (yes or no).
  - Free lime: by Adding to the soil few drops of HCl to know if the soil was strongly calcareous, calcareous, slightly calcareous or non calcareous.
- Rocks: in each plot the following characters were measured:
  - Abundance%
  - Type: Basalt, light limestone, or dark limestone.
  - Weathered (fresh, weathered or rotten).
- Stones: in each plot the following characters were measured:
  - Abundance%
  - Type: Basalt, light limestone, or dark limestone.
  - Size class: the range from (0.2 cm-more than 60 cm).
- Species Survey: both in herbaceous plot and trees plot Date of survey, surveyors, and plot size were recorded.
  - In Herbaceous Plots: the following measurements were recorded:
    - List of Species: including botanical name, author, family, Arabic name, life cycle (annual, perennial or biennial) and biotype (trees, shrub, herb or climber), the known species directly recorded in the field, plant species which could not be identified in the field were given a code, collected and labeled, these specimens were compared with herbarium material of ICARDA, and by using flora of Syria, Palestine (reference 1, 2, 3, 5, 8,10,11,12 and 13)
    - Plant Cover%: for each species
    - Density: number of plants for each species/plot
    - Growth Stage: leaf stage, flower or fruiting
    - Health: healthy or stressed (by disease, insect, parasite, cutting and burn or grazing)
    - Dominant and Associated Species: in each plot
    - In Tree Plots: in addition to previous data of herbaceous plots, a special data for trees were also recorded:
    - Number of each adult trees
    - Height and diameter of each adult trees
    - Number of seedlings and juvenile trees
- Degradation Factors: these data were recorded in monitoring level
  - General Factors: the scale was 0 (none or very low), 3 (low), 5(medium),7(high), and including:(overgrazing, urbanization, cropland encroachment, cutting, terracing, destoning, other land reclamation, quarries or fire.
  - Botanical Indicators: recording the list of the indicator species of degradation, containing thistles, poisonous and unpalatable herb and shrubs for sheep and goats and poisonous bulbous plants.

**Table 3.** Multi-uses of major native species (data obtained from local knowlegement of community).

| Species | Medicinal | Aromatic | Honey Production | Ornamental | Wood | Forage | Industrial Purposes | Foods |
|---|---|---|---|---|---|---|---|---|
| *Styrax officinalis* Snow drop bush | √ | √ | √ | √ | √ | √ | √ | |
| *Laurus nobilis* Laurel | √ | √ | √ | √ | | | √ | √ |
| *Crataegus azarolus* Hawthorn | √ | | √ | | √ | √ | √ | √ |
| *Pistacia palaestina* Terebinth | √ | | | √ | √ | √ | √ | √ |
| *Rhus coriaria* Sumac | √ | | √ | √ | | √ | √ | √ |
| *Quercus calliprinos* Palestine oak | √ | | | | √ | √ | √ | √ |
| *Amygdalus orientalis* Wild almond | √ | √ | √ | | | | √ | √ |
| *Capparis spinosa* Capers | √ | | | | | √ | √ | √ |

## Results

Based on the botanical survey conducted by ICARDA in the oak forest in the Idleb area from March-June 2007, about 58 families, 220 genus and 338 species-with 75 medicinal, the medicinal plants defined by local knowlege of the community plants species were recorded. The study involved herbaceous plants and trees.

The medicinal plant species consist of 12 tree species, 20 shrub and 43 herb species.

Some examples of the role of medicinal plants in improving the incomes of rural poor, which the rural community informed us of:

- Collecting the fruit of laurel by rural poor to extract the oil and selingl it to the factory of natural laurel health soap.
- Collecting the fruit of sumac and selling it to the local market to be used as medicine, food and dye.
- Collecting the flower buds and roots of capers to be sold as medicine and food to other countries (Turkey).
- Collecting flowers, leaves or fruits of many medicinal plants for household consumption and to be sold to pharmaceutical companies that depend on medicinal plants.

### Threats Facing Medicinal Plants in Oak Forests

Medicinal plants are threatened by the following factors of degradation:

- Cultivation methods enhance wind erosion
- Excessive removal of woody plants for fuel.
- Some trees are cut and burned annually to be used as a source of energy for cooking.

**Table 4.** The most important medicinal plant species collected from Oak forests by the rural poor, and sold in local markets (data obtained from the local market in Syria).

| Species | Price (USS/kg) | Part used | Uses |
|---|---|---|---|
| *Matricaria chamomilla*, Camomile | 10 | Whole plant | Upset stomach, bronchitis |
| *Thymus syriacus*, Thyme | 6 | Leaves | Cough, ulcer |
| *Micromeria myrtifolia*, Myrtle-leaved Savory | 5 | Leaves & flowers | Asthma |
| *Crataegus azarolus*, Azarole Hawthorn | 3.5 | Flowers | Strengthens the heart |
| *Rhus coriaria*, Leafed Sumac | 3 | Fruits | Relief from fever |
| *Capparis spinosa*, Capers | 3 | Flower buds, roots | Diarrhea, ulcer |
| *Pistacia palaestina*, Terebinth | 1.5 | Fruits | Sedative the pains |
| *Quercus calliprinos*, Holm Oak | 1 | Bark & fruits | Eczema, antacid |
| *Laurus nobilis*, Greek Laurel | 1 | Leaves | Vomiting, eczema |

- Overgrazing by sheep and goats and poor range management.
- The use of nature often takes place against backdrop of uncontrolled exploitation or consumption.
- Rock removal, cultivation and planting of fruit trees or annual crops.
- Quarrying for limestone and other rocks for building purposes.
- Terracing of the land for planting agricultural crops.
- Some tree groups and herbaceous plants have suffered from human impact.

Reasons for Conserving Plant Diversity: (reference 7)
- All plants are important and essential to life, and the rural poor depend on plants for their survival, food, medicines, clothing, shelter and fuel.
- Necessary actions include limited human impact on the biosphere, maintaining biological wealth, promoting technologies that increase benefits to help the rural poor.

Recommendations for Conservation of Medicinal Plants and How to Help the Rural Poor: (reference: 4 and 6)
- Compilation of a list of species that may be under threat.
- Rural development is a frequently stated purpose of aid programs, the overall goal to alleviate poverty, unemployment and poor health.
- A further component of rural development is maintenance and rehabilitation ecosystems

## Acknowledgments

We would like to thank the botanical survey field team: Mr. Abdul Karem Hamade and Ms. Enas Jumbaz, and also we thank Ms. Reem Shabe Kalyeh for entering data base for botanical survey and Ms. Rima El-Khatib for formatting the report.

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## Appendix 1. List of species in herbaceous plots and tree plots in both areas (Al-Zaweyeh &Al-Wastani Mountains).

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 1 | *Adonis aestivalis* | L. | Ranunculaceae | دحنون | A | H |
| 2 | *Adonis annua* | L. | Ranunculaceae | الدحنون | A | H |
| 3 | *Aegilops geniculata* | Roth | Gramineae | حشيشة الماعز | A | H |
| 4 | *Aegilops ovata* | L. | Gramineae | حشيشة الماعز | A | H |
| 5 | *Aegilops triuncialis* | L. | Gramineae | حشيشة الماعز | A | H |
| 6 | *Ainsworthia trachycarpa* | Boiss. | Umbelliferae | | A | H |
| 7 | *Ajuga chia* | Schreb. | Labiatae | عشبة الدم | P | H |
| 8 | *Ajuga orientalis* | L. | Labiatae | عشبة الدم | P | H |
| 9 | *Alhagi maurorum* | Medik. | Leguminosae | عاقول مغربي | P | S-Sh |
| 10 | *Allium scorodoprasum* | L. | Alliaceae | بصل بري , زعيتمان | P | H |
| 11 | *Allium stamineum* | Boiss. | Alliaceae | بصل بري | P | H |
| 12 | *Alopecurus utriculatus* | Banks & Sol. | Gramineae | ذنب الثعلب | A | H |
| 13 | *Alyssum damascenum* | Boiss.et Gaill. | Cruciferae | دريهمة دمشقية | A | H |
| 14 | *Alyssum minus* | (L.) Rothm. | Cruciferae | دريهمة صغيرة | A | H |
| 15 | *Amygdalus orientalis* | Duh. | Rosaceae | لوز بري | P | H-Sh |
| 16 | *Anagallis arvensis* | L. | Primulaceae | خزام العروس, اذان الفار | A | H |
| 17 | *Anagyris foetida* | L. | Leguminosae | خروب الخنزير | P | S-Sh |
| 18 | *Anchusa strigosa* | Banks & Sol. | Boraginaceae | لسان الثور | P | H |
| 19 | *Andrachne telephioides* | L. | Euphorbiaceae | بذر الدود | P | H |
| 20 | *Anemone coronaria* | L. | Ranunculaceae | انيمون | P | H |
| 21 | *Anthemis cornucopiae* | Boiss. | Compositae | زهرة اللبن , اربيان | A | H |
| 22 | *Anthemis cotula* | L. | Compositae | زهرة اللبن , اربيان | A | H |
| 23 | *Anthemis maris-mortui* | Eig | Compositae | زهرة اللبن , اربيان | A | H |
| 24 | *Arabis aucheri* | Boiss. | Cruciferae | زهرة عربية | A | H |
| 25 | *Arbutus andrachne* | L. | Ericaceae | قطلب | P | T |
| 26 | *Aristolochia maurorum* | L. | Aristolochiaceae | خيار الغنم | P | H |
| 27 | *Artedia squamata* | L. | Umbelliferae | | A | H |
| 28 | *Arum palaestinum* | Boiss. | Araceae | اللوف | P | H |
| 29 | *Asparagus acutifolius* | L. | Asparagaceae | الهليون | P | S-Sh |
| 30 | *Asphodeline lutea* | (L.) Reichenb.. | Asphodelaceae | ابو صوي | P | H |
| 31 | *Asphodelus microcarpus* | Salzm. & Viv. | Asphodelaceae | عيصلان | P | H |
| 32 | *Astragalus asterias* | Steven | Leguminosae | قفعاء متصالبة | A | H |
| 33 | *Astragalus hamosus* | L. | Leguminosae | قفعاء شصية | A | H |
| 34 | *Astragalus palaestinus* | Eig | Leguminosae | قفعاء فلسطينية | A | H |
| 35 | *Atractylis cancellata* | L. | Compositae | جلوة متحابكة | A | H |
| 36 | *Avena barbata* | Pott ex link | Gramineae | شوفان لحوي | A | H |
| 37 | *Avena sterilis* | L. | Gramineae | شوفان عقيم | A | H |
| 38 | *Ballota saxatilis* | Sieb.ex C. Presl | Labiatae | بلوتا | P | S-Sh |
| 39 | *Bellevalia flexuosa* | Boiss. | Hyacinthaceae | بصيل متدلي | P | H |
| 40 | *Bellevalia stepporum* | Feinbr. | Hyacinthaceae | بصيل | P | H |
| 41 | *Bifora testiculata* | (L.) Spreng.ex Schult. | Umbelliferae | كزبرة صغيرة | A | H |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 42 | *Biscutella didyma* | L. | Cruciferae | خردل منحني, مشبك | A | H |
| 43 | *Biserrula pelecinus* | L. | Leguminosae | | A | H |
| 44 | *Bituminaria bituminosa* | (L.) Stirton. | Leguminosae | | P | H |
| 45 | *Bolanthus filicaulis* | (Boiss.) Barkoudah | Caryophyllaceae | | P | H |
| 46 | *Bongardia chrysogonum* | (L.) Sp. | Berberidaceae | | P | H |
| 47 | *Brassica nigra* | (L.) Koch | Cruciferae | خردل اسود | A | H |
| 48 | *Briza maxima* | L. | Gramineae | ابريزة, قصفة | A | H |
| 49 | *Bromus alopecuros subsp. caroli-henrici* | (Greuter) P. M. Smith | Gramineae | شويعرة | A | H |
| 50 | *Bromus danthoniae* | Trin. | Gramineae | شويعرة | A | H |
| 51 | *Bromus diandrus* | Roth | Gramineae | شويعرة | A | H |
| 52 | *Bromus lanceolatus var. lanatus* | kergue'len | Gramineae | شويعرة مستدقة | A | H |
| 53 | *Bromus tectorum* | L. | Gramineae | شويعرة | A | H |
| 54 | *Bryonia cretica* | L. | Cucurbitaceae | قريعة الشيخ | P | C-H |
| 55 | *Bupleurum brevicaule* | Schlecht. | Umbelliferae | حلوان | A | H |
| 56 | *Calendula arvensis* | L. | Compositae | اقحوان بري | A | H |
| 57 | *Callipeltis cucullaria* | (L.) Stev. | Rubiaceae | | A | H |
| 58 | *Calycotome villosa* | (Poir.) Link. | Leguminosae | الجربان | P | S-Sh |
| 59 | *Campanula erinus* | L. | Campanulaceae | جرسية | A | H |
| 60 | *Campanula strigosa* | Banks & Sol. | Campanulaceae | زهرة الجرس الشوكية | A | H |
| 61 | *Capparis spinosa* | L. | Capparaceae | القبار, الشفلح | P | H-Sh |
| 62 | *Capsella bursa-pastoris* | (L.) Medik. | Cruciferae | كيس الراعي | A | H |
| 63 | *Carduncellus eriocephalus* | Boiss. | Compositae | | P | H |
| 64 | *Carduus pycnocephalus* | (Jacq.) Boiss. | Compositae | لسان الكلب | A | H |
| 65 | *Carex stenophylla* | Wahlenb. B. | Cyperaceae | نميص | P | H |
| 66 | *Carthamus persicus* | Willd. | Compositae | عصفر فارسي | A | H |
| 67 | *Catapodium rigidum* | (L.) C. E. Hubbard | Gramineae | | A | H |
| 68 | *Caucalis tenella* | Del. | Umbelliferae | | A | H |
| 69 | *Centaurea iberica* | Trev.ex Spreng | Compositae | مرار | B | H |
| 70 | *Centaurea pallescens* | Del. | Compositae | دردار, مرار | A | H |
| 71 | *Cerasus avium* | L. Moench | Rosaceae | كرز | P | T |
| 72 | *Cerasus mahaleb* | (L.) Mill. | Rosaceae | المحلب | P | T |
| 73 | *Ceratocephala falcata* | (L.) Pers. | Ranunculaceae | خشينة منجلية | A | H |
| 74 | *Chardinia orientalis* | (L.) O. Kuntze | Compositae | كاردينيا | A | H |
| 75 | *Cichorium pumilum* | Jacq. | Compositae | هندباء برية | A | H |
| 76 | *Cistus creticus* | L. | Cistaceae | قريضة , لباد | P | S-Sh |
| 77 | *Clematis cirrhosa* | L. | Ranunculaceae | مدادة | P | C-Sh |
| 78 | *Convolvulus dorycnium* | L. | Convolvulaceae | مداد بنفسجي | P | H |
| 79 | *Coronilla rostrata* | Boiss. et Sprun. | Leguminosae | قرينة منقارية | A | H |
| 80 | *Coronilla scorpioides* | (L.) Koch | Leguminosae | قرينة عقربية | A | H |
| 81 | *Crataegus azarolus* | L. | Rosaceae | زعرور بري | P | T |
| 82 | *Crepis sancta* | (L.) Bornm. | Compositae | حلاوى | A | H |
| 83 | *Crucianella ciliata* | Lam. | Rubiaceae | لامة | A | H |
| 84 | *Crucianella latifolia* | L. | Rubiaceae | هزيل | A | H |
| 85 | *Cruciata articulata* | (L.) Ehrendf. | Rubiaceae | | A | H |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 86 | *Crupina crupinastrum* | (Moris) Vis. | Compositae | كروبينا | A | H |
| 87 | *Cynodon dactylon* | (L.) Pers. | Gramineae | النجيل الأصبعي | P | H |
| 88 | *Cynosurus elegans* | Desf. | Gramineae | ذنب الكلب | A | H |
| 89 | *Dactylis glomerata* | L. | Gramineae | اصبعية متكتلة | P | H |
| 90 | *Daphne oleifolia* | Lam. | Thymelaeaceae | فسفوسة العنزة, دفنة زيتونية | P | H-Sh |
| 91 | *Dianthus strictus* | Banks & Sol. | Caryophyllaceae | قرنفل بري | P | H |
| 92 | *Echinaria capitata* | (L.) Desf. | Gramineae | عشب خشن, شائك | A | H |
| 93 | *Echinops gaillardotii* | Boiss. | Compositae | شوك الجمال | P | H |
| 94 | *Echinops polyceras* | Boiss. | Compositae | شوك الجمال الأزرق | P | H |
| 95 | *Eminium spiculatum* | (Blume.) Schott. | Araceae | امينون سنيبلي | P | H |
| 96 | *Ephedra peduncularis* | Boiss. | Ephedraceae | علندى | P | C-SH |
| 97 | *Erodium cicutarium* | (L.) L' He'r. | Geraniaceae | ابرة العجوز, البختري | A | H |
| 98 | *Erodium gruinum* | (L.) L' He'r. | Geraniaceae | قرنوة | A | H |
| 99 | *Erodium subintegrifolium* | Eig | Geraniaceae | قرنوة | A | H |
| 100 | *Eryngium creticum* | Lam. | Umbelliferae | قرصعنة , شنداب صحراوي | P | H |
| 101 | *Eryngium glomeratum* | Lam. | Umbelliferae | قرصعنة , شنداب صحراوي | P | H |
| 102 | *Euphorbia aleppica* | L. | Euphorbiaceae | لبينة | A | H |
| 103 | *Euphorbia densa* | Schrenk | Euphorbiaceae | لبينة | A | H |
| 104 | *Euphorbia exigua* | L. | Euphorbiaceae | لبينة | A | H |
| 105 | *Euphorbia helioscopia* | L. | Euphorbiaceae | لبينة | A | H |
| 106 | *Euphorbia reuteriana* | Boiss. | Euphorbiaceae | لبينة | A | H |
| 107 | *Fibigia clypeata* | (L.) Medik. | Cruciferae | درهمية | P | H |
| 108 | *Ficus carica* | L. | Moraceae | تين بري | P | T |
| 109 | *Filago contracta* | (Boiss.) Chrteh & Holub | Compositae | قطينة | A | H |
| 110 | *Filago pyramidata* | L. | Compositae | قطينة هرمية | A | H |
| 111 | *Gagea chlorantha* | (Bieb.) Schult. & Schult.fil. | Liliaceae | لحية التيس | P | H |
| 112 | *Galium aparine* | L. | Rubiaceae | دبيقة | A | H |
| 113 | *Galium hierochuntinum* | Bornm. | Rubiaceae | دبيقة | A | H |
| 114 | *Galium setaceum* | Lam. | Rubiaceae | دبيقة مخرزية | A | H |
| 115 | *Geranium columbinum* | L. | Geraniaceae | غرنوق | A | H |
| 116 | *Geranium tuberosum* | L. | Geraniaceae | غرنوق | P | H |
| 117 | *Geropogon hybridus* | (L.) Sch. Bip. | Compositae | ذيل الفرس | P | H |
| 118 | *Gladiolus aleppicus* | Boiss. | Iridaceae | سيفية حلبية | P | H |
| 119 | *Gundelia tournefortii* | L. | Compositae | سلبين | P | H |
| 120 | *Gynandriris sisyrinchium* | (L.) Parl. | Iridaceae | سوسن البادية | P | H |
| 121 | *Hedypnois rhagadioloides* | (L.) F.W.Schmidt emend.spreng | Compositae | | A | H |
| 122 | *Helianthemum salicifolium* | (L.) Mill. | Cistaceae | جردة الكمأة | A | H |
| 123 | *Herniaria hisuta* | L. | Illecebraceae | ام لبيدة | A | H |
| 124 | *Hippocrepis unisiliquosa* | L. | Leguminosae | حدويات | A | H |
| 125 | *Hirschfeldia incana* | (L.) Lagreze-Fossat | Cruciferae | هرشفيلديا | A | H |
| 126 | *Hordeum bulbosum* | L. | Gramineae | شعير بصيلي | P | H |
| 127 | *Hordeum glaucum* | Steud. | Gramineae | شعير بري | A | H |
| 128 | *Hordeum murinum* | L. | Gramineae | ابو شويرب | A | H |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 129 | *Hordeum spontaneum* | C. Koch | Gramineae | شعير بري (عفوي) | A | H |
| 130 | *Hordeum vulgare* | L. | Gramineae | شعير مزروع | A | H |
| 131 | *Hymenocarpos circinatus* | (L.) Savi | Leguminosae | نفل مدور | A | H |
| 132 | *Hypecoum procumbens* | L. | Papaveraceae | بربارة | A | H |
| 133 | *Hypericum triquetrifolium* | Turra | Guttiferae | هيبيريكم ثلاثي الاوراق | P | H |
| 134 | *Iberis odorata* | L. | Cruciferae | قضامة الحمامة | A | H |
| 135 | *Inula viscosa* | (L.) Ait. | Compositae | طيون | P | S-Sh |
| 136 | *Iris histrio* | Reichenb.fil. | Iridaceae | سوسن | P | H |
| 137 | *Juniperus oxycedrus* | L. | Cupressaceae | شربين, عرعر شربيني | P | T |
| 138 | *Koeleria phleoides* | (Vill.) Pers. | Gramineae | قنبوع | A | H |
| 139 | *Lactuca serriola* | L. | Compositae | خسيس | P | H |
| 140 | *Lactuca tuberosa* | Jacq. | Compositae | خسيس | B | H |
| 141 | *Lagoecia cuminoides* | L. | Umbelliferae | حشيشة الذهب | A | H |
| 142 | *Lathyrus aphaca* | L. | Leguminosae | جلبان | A | H |
| 143 | *Lathyrus blepharicarpus* | Boiss. | Leguminosae | جليبينة | A | H |
| 144 | *Lathyrus cicera* | L. | Leguminosae | جلبان | A | H |
| 145 | *Lathyrus digitatus* | (M.Bieb.) Foiri | Leguminosae | جلبان | A | H |
| 146 | *Lathyrus hierosolymitanus* | Boiss. | Leguminosae | جلبان | A | H |
| 147 | *Lathyrus marmoratus* | Boiss. & Blanche | Leguminosae | جلبان | A | H |
| 148 | *Laurus nobilis* | L. | Lauraceae | الغار | P | T-T |
| 149 | *Lens ervoides* | (Brignoli) Grande | Leguminosae | عدس بري | A | H |
| 150 | *Lens orientalis* | (Boiss.) Schmalh. | Leguminosae | عدس بري | A | H |
| 151 | *Leopoldia comosa* | (L.) Parl. | Hyacinthaceae | بصيل ازرق شائع | P | H |
| 152 | *Leopoldia eburnea* | Eig & Feinbr. | Hyacinthaceae | بصيل ازرق | P | H |
| 153 | *Lepidium spinescens* | DC. | Cruciferae | رشاد بري | A | H |
| 154 | *Linaria joppensis* | Bornm. | Scrophulariaceae | حلاوة | A | H |
| 155 | *Linum pubescens* | Banks et Sol. | Linaceae | كتان مزغب | A | H |
| 156 | *Linum strictum* | L. | Linaceae | كتان بري | A | H |
| 157 | *Lobularia libyca* | (Viv.) C. F. W. Meissn. | Cruciferae | | A | H |
| 158 | *Lolium rigidum* | Gaudin | Gramineae | حشيشة الشيلم | A | H |
| 159 | *Lonicera orientalis* | Lam. | Caprifoliaceae | العسلة (عراتلي شرقي) | P | C-Sh |
| 160 | *Lotus halophilus* | Boiss. & Sprun. | Leguminosae | رجل العصفور | A | H |
| 161 | *Lycium depressum* | Stocks | Solanaceae | العوسج | P | H-Sh |
| 162 | *Medicago aculeata var. aculeata* | Gaertn. | Leguminosae | نفل شوكي | A | H |
| 163 | *Medicago blancheana var. blancheana* | Boiss. | Leguminosae | نفل ابيض | A | H |
| 164 | *Medicago blancheana var. bonarotiana* | (Arc.) Arc. | Leguminosae | نفل ابيض | A | H |
| 165 | *Medicago constricta* | Dur. | Leguminosae | نفل متراص | A | H |
| 166 | *Medicago coronata* | (L.) Bart. | Leguminosae | نفل تاجي | A | H |
| 167 | *Medicago laciniata* | (L.) Miller. | Leguminosae | نفل مفصص الاوراق | A | H |
| 168 | *Medicago minima var. minima* | (L.) Bart. | Leguminosae | نفل الصغير القرون | A | H |
| 169 | *Medicago orbicularis f.* | (L.) Bart. | Leguminosae | النفل الزري | A | H |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| | *marginata* | | | | | |
| 170 | *Medicago polymorpha var. polymorpha* | L. | Leguminosae | نفل متعدد الاشكال | A | H |
| 171 | *Medicago polymorpha var. vulgaris* | (Benth.) Shinners | Leguminosae | نفل متعدد الاشكال | A | H |
| 172 | *Medicago radiata* | L. | Leguminosae | نفل شعاعي | A | H |
| 173 | *Medicago rigidula var. agrestis* | Burnat | Leguminosae | نفل قاسي | A | H |
| 174 | *Medicago rigidula var. cinerascens* | (Jord.) Rouy | Leguminosae | نفل قاسي | A | H |
| 175 | *Medicago rigidula var. rigidula* | (L.) All. | Leguminosae | نفل قاسي | A | H |
| 176 | *Medicago rigidula var. submitis* | (Boiss.) Heyn | Leguminosae | نفل قاسي | A | H |
| 177 | *Medicago turbinata var. turbinata* | (L.)All. | Leguminosae | نفل توربيني القرون | A | H |
| 178 | *Melica cupani* | Guss. | Gramineae | | P | H |
| 179 | *Mercurialis annua* | L. | Euphorbiaceae | حلبلوب, خسة | A | H |
| 180 | *Micromeria myrtifolia* | Boiss. & Hohen. | Labiatae | شاي بري (زوفا) | P | S-Sh |
| 181 | *Minuartia decipiens* | (Fenzl) Bornm. | Caryophyllaceae | ابو حريبة زهري | A | H |
| 182 | *Muscari racemosum* | (L.) Mill. | Hyacinthaceae | كحلة الكلب, اجراس زرقاء | P | H |
| 183 | *Nardurus maritimus* | (L.) | Gramineae | | A | H |
| 184 | *Nigella unguicularis* | (Poir.) Spenn. | Ranunculaceae | حبة سوداء | A | H |
| 185 | *Noaea mucronata* | (Forssk.) Asch. & Schweinf. | Chenopodiaceae | الصر | P | S-Sh |
| 186 | *Notobasis syriaca* | (L.) Cass. | Compositae | الخرفيش الكبير | A | H |
| 187 | *Olea europeae* | L. | Oleaceae | زيتون مزروع | P | T |
| 188 | *Olea europeae var. oleaster* | (Hoffmgg. & Link) D. C | Oleaceae | زيتون بري | P | H-Sh |
| 189 | *Onobrychis aequidentata* | (Sm.) Urv. | Leguminosae | قطب متساوي التسنن | A | H |
| 190 | *Onobrychis caput-galli* | (L.) Lam. | Leguminosae | قطب راس الديك | A | H |
| 191 | *Onobrychis crista-galli* | (L.) Lam. | Leguminosae | قطب عرف الديك | A | H |
| 192 | *Ononis antiquorum* | L. | Leguminosae | الشبرق | P | S-Sh |
| 193 | *Ononis natrix* | L. | Leguminosae | شبرق اصفر, نشيحة | P | S-Sh |
| 194 | *Ononis reclinata* | L. | Leguminosae | شبرق | A | H |
| 195 | *Ononis sicula* | Guss. | Leguminosae | اللتين السيسلي | A | H |
| 196 | *Ononis viscosa* | L. | Leguminosae | شبرق | A | H |
| 197 | *Onopordum heteracanthum* | C.A.Mey. | Compositae | قندريس | B | H |
| 198 | *Orchis sancta* | L. | Orchidaceae | الأوركيد المقدس | P | H |
| 199 | *Orlaya daucoides* | (L.) Greuter | Umbelliferae | | A | H |
| 200 | *Ornithogalum divergens* | Boreau | Hyacinthaceae | لبن الطير | P | H |
| 201 | *Oryzopsis miliacea* | (L.) Aschers. & Schweinf. | Gramineae | حشيشة رزية ناعمة | P | H |
| 202 | *Osyris alba* | L. | Santalaceae | خصوميا | P | S-Sh |
| 203 | *Pallenis spinosa* | (L.) Cass. | Compositae | بخور مريم | A | H |
| 204 | *Papaver polytrichum* | Boiss.et Ky. | Papaveraceae | شقشقيق | A | H |
| 205 | *Papaver rhoeas* | L. | Papaveraceae | شقائق النعمان | A | H |
| 206 | *Parentucellia flaviflora* | (Boiss.) Nevski | Scrophulariaceae | | A | H |
| 207 | *Paronychia palaestina* | Eig | Illecebraceae | حربث فضي (علك الغزال) | P | H |
| 208 | *Peganum harmala* | L. | Zygophyllaceae | حرمل | P | S-Sh |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 209 | *Phagnalon barbeyanum* | Aschers.et Schweinf. | Compositae | طعام الأرنب | P | S-Sh |
| 210 | *Phalaris minor* | Retz. | Gramineae | مجنحة صغرى | A | H |
| 211 | *Phillyrea latifolia* | L. | Oleaceae | الزرود- بجس | P | S-T |
| 212 | *Phleum subulatum* | (Savi) Aschers. & Graebn. | Gramineae | عصوية | A | H |
| 213 | *Phlomis orientalis* | Mill. | Labiatae | اللهيب | P | S-Sh |
| 214 | *Phlomis platystegia* | Post | Labiatae | لهيب | P | S-Sh |
| 215 | *Phlomis syriaca* | Boiss. | Labiatae | لهيب | P | S-Sh |
| 216 | *Picnomon acarna* | (L.) Cass. | Compositae | شوك الفار, شوك ابيض | A | H |
| 217 | *Picris damascena* | Boiss. & Gaill. | Compositae | حوذان دمشقي | A | H |
| 218 | *Pimpinella eriocarpa* | Banks et Sol. | Umbelliferae | انيسون صوفي الثمر | A | H |
| 219 | *Pinus pinea* | L. | Pinaceae | صنوبر ثمري | P | T |
| 220 | *Pistacia palaestina* | Boiss. | Anacardiaceae | البطم الفلسطيني | P | T |
| 221 | *Pistacia vera* | L. | Anacardiaceae | فستق حلبي | P | T |
| 222 | *Pisum elatius* | M. B. | Leguminosae | بازلاء برية | A | H |
| 223 | *Plantago cretica* | L. | Plantaginaceae | زباد, ربل | A | H |
| 224 | *Plantago indica* | L. | Plantaginaceae | لسان الحمل, ربل, زباد | A | H |
| 225 | *Plantago lanceolata* | L. | Plantaginaceae | ربل رمحي الأوراق | P | H |
| 226 | *Plantago ovata* | Forssk. | Plantaginaceae | زباد بيضوي | A | H |
| 227 | *Poa bulbosa* | L. | Gramineae | قبا بصيلي | P | H |
| 228 | *Poa sinaica* | Steud. | Gramineae | قبا سينائي | P | H |
| 229 | *Polycarpaea repens* | (Forssk.) Aschers.et Schweinf. | Caryophyllaceae | كميلة, دقيقة | P | H |
| 230 | *Polycarpon tetraphyllum* | (L.) L. | Caryophyllaceae | بوليكربون | A | H |
| 231 | *Prunus microcarpa* | C. A. Mey | Rosaceae | خوخ بري - برقروق | P | H-Sh |
| 232 | *Prunus ursina* | Ky. | Rosaceae | خوخ الدب | P | S-T |
| 233 | *Psilurus incurvus* | (Gouan) Sching & Thell. | Gramineae | | A | H |
| 234 | *Pterocephalus involucratus* | (Sm.) Spreng. | Dipsacaceae | | A | H |
| 235 | *Pterocephalus pulverulentus* | Boiss.et Bl. | Dipsacaceae | | P | S-Sh |
| 236 | *Pyrus syriaca* | Boiss. | Rosaceae | اجاص سوري (بري) | P | T |
| 237 | *Quercus aegilops* | L. | Fagaceae | سنديان الماعز | P | T |
| 238 | *Quercus calliprinos* | Webb | Fagaceae | السنديان العادي | P | T |
| 239 | *Quercus infectoria* | Oliv. | Fagaceae | السنديان البلوطي -العفصي | P | S-T |
| 240 | *Quercus libani* | Oliv. | Fagaceae | السنديان اللبناني | P | T |
| 241 | *Ranunculus asiaticus* | L. | Ranunculaceae | حوذان | P | H |
| 242 | *Ranunculus millefolius* | Banks & Sol. | Ranunculaceae | حوذان | P | H |
| 243 | *Reichardia tingitana* | (L.) Roth | Compositae | عضيد | A | H |
| 244 | *Rhagadiolus stellatus* | (L.) Gaertn. | Compositae | رويس | A | H |
| 245 | *Rhamnus palaestinus* | Boiss. | Rhamnaceae | السويد الفلسطيني | P | H-Sh |
| 246 | *Rhaponticum pusillum* | (Labill.) Boiss. | Compositae | الراوندي الضئيل | P | H |
| 247 | *Rhus coriaria* | L. | Anacardiaceae | السماق | P | T |
| 248 | *Roemeria hybrida* | (L.) DC. | Papaveraceae | نعمانة | A | H |
| 249 | *Rosa conina* | L. | Rosaceae | ورد نسريني | P | H-Sh |
| 250 | *Rumex cassius* | Boiss. | Polygonaceae | حميض | P | H |
| 251 | *Salvia horminum* | L. | Labiatae | مردكوش | A | H |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 252 | *Salvia indica* | L. | Labiatae | لسينة هندية | P | H |
| 253 | *Salvia multicaulis* | Vahl | Labiatae | مريمية | P | S-Sh |
| 254 | *Salvia viridis* | L. | Labiatae | نوارة المرج | A | H |
| 255 | *Sanguisorba minor* | Scop. | Rosaceae | كزبرة البئر | P | H |
| 256 | *Sarcopoterium spinosum* | (L.) Sp. | Rosaceae | البلان | P | S-Sh |
| 257 | *Scabiosa palaestina* | L. | Dipsacaceae | ثليجة فلسطينية | A | H |
| 258 | *Scandix iberica* | M. B. | Umbelliferae | ابو مغيزلة, ابرة الراعي | A | H |
| 259 | *Scandix pecten-veneris* | L. | Umbelliferae | ابو مغيزلة, مشط الراعي | A | H |
| 260 | *Scandix stellata* | Banks et Sol. | Umbelliferae | ابو مغيزلة | A | H |
| 261 | *Scolymus hispanicus* | L. | Compositae | شوكة الفار | B | H |
| 262 | *Scorpiurus muricata* | L. | Leguminosae | عنجل | A | H |
| 263 | *Scorzonera papposa* | DC. | Compositae | ضبح | P | H |
| 264 | *Scorzonera schweinfurthii* | Boiss. | Compositae | ضبح | P | H |
| 265 | *Scrophularia hierochuntina* | Boiss. | Scrophulariaceae | خنازيرية | B | H |
| 266 | *Sedum nicaeense* | All. | Crassulaceae | | P | H |
| 267 | *Senecio vernalis* | Waldst. & Kit. | Compositae | زمروق | A | H |
| 268 | *Serratula cerinthifolia* | (Sm.) Boiss. | Compositae | وريقة | P | H |
| 269 | *Silene aegyptiaca* | (L.) L.f. | Caryophyllaceae | احلوان | A | H |
| 270 | *Silene damascena* | Boiss.et Gaill. | Caryophyllaceae | دبقة | A | H |
| 271 | *Silene muscipula* | L. | Caryophyllaceae | دبقة | A | H |
| 272 | *Silene tridentata* | Desf. | Caryophyllaceae | دبقة ثلاثية التسنن | A | H |
| 273 | *Silybum marianum* | (L.) Gaertn. | Compositae | خرفيش | A | H |
| 274 | *Sinapis arvensis* | L. | Cruciferae | صفيرة , فجيلة, خردل بري | A | H |
| 275 | *Smilax aspera* | L. | Smilacaceae | خصيات الديك | P | C-Sh |
| 276 | *Sonchus oleraceus* | L. | Compositae | علك | A | H |
| 277 | *Sonchus tenerrimus* | L. | Compositae | علك | A | H |
| 278 | *Spergula fallax* | (Lowe) Krause | Caryophyllaceae | قليقلة | A | H |
| 279 | *Spergularia diandra* | (Guss.) Heldr. & Sart. | Caryophyllaceae | ام ثريب | A | H |
| 280 | *Stachys arvensis* | (L.) L. | Labiatae | ثلجية , غبيراء | A | H |
| 281 | *Stachys longispicata* | Boiss.et Ky. | Labiatae | ثليجة طويلة السنبلة | P | H |
| 282 | *Stipa capensis* | Thunb. | Gramineae | عزم | A | H |
| 283 | *Stipa parviflora* | Desf. | Gramineae | عزم صغير الأزهار | P | H |
| 284 | *Styrax officinalis* | L. | Styracaceae | الإصطرك -العبهر | P | S-T |
| 285 | *Taeniatherum crinitum* | (Shreb.) Nevski | Gramineae | | A | H |
| 286 | *Teucrium polium* | L. | Labiatae | قريصة , الجعدة | P | S-Sh |
| 287 | *Thlaspi perfoliatum* | L. | Cruciferae | شمرمورة | A | H |
| 288 | *Thymus syriacus* | Boiss. | Labiatae | زعتر سوري بري | P | S-Sh |
| 289 | *Tordylium syriacum* | L. | Umbelliferae | عشبة الأيل | A | H |
| 290 | *Torilis leptophylla* | (L.) Reichb.f. | Umbelliferae | بقدونس بري | A | H |
| 291 | *Trachynia distachya* | (L.) Link | Gramineae | شعيرة | A | H |
| 292 | *Tragopogon buphthalmoides* | (DC.) Boiss. | Compositae | ذنب الفرس | P | H |
| 293 | *Trifolium argutum* | Banks & Sol. | Leguminosae | برسيم | A | H |
| 294 | *Trifolium arvense* | L. | Leguminosae | برسيم الحقول | A | H |
| 295 | *Trifolium boissieri* | Guss.ex Boiss. | Leguminosae | برسيم بوزيري | A | H |
| 296 | *Trifolium bullatum* | Boiss.et Hausskn. | Leguminosae | برسيم قطني | A | H |

| No. | Species | Author | Family | Arabic name | Life form | Biotype |
|---|---|---|---|---|---|---|
| 297 | *Trifolium campestre* | Schreb. | Leguminosae | برسيم اصفر | A | H |
| 298 | *Trifolium cherleri* | L. | Leguminosae | برسيم | A | H |
| 299 | *Trifolium clypeatum* | L. | Leguminosae | برسيم درعي | A | H |
| 300 | *Trifolium dasyurum* | C. Persl | Leguminosae | برسيم | A | H |
| 301 | *Trifolium isthmocarpum* | Brot. | Leguminosae | برسيم | A | H |
| 302 | *Trifolium nigrescens* | Viv. | Leguminosae | برسيم اسود | A | H |
| 303 | *Trifolium pauciflorum* | Urv. | Leguminosae | برسيم | A | H |
| 304 | *Trifolium physodes* | Stev.ex M. B. | Leguminosae | برسيم | A | H |
| 305 | *Trifolium pilulare* | Boiss. | Leguminosae | برسيم | A | H |
| 306 | *Trifolium purpureum* | Loisel. | Leguminosae | برسيم بنفسجي | A | H |
| 307 | *Trifolium scabrum* | L. | Leguminosae | برسيم خشن | A | H |
| 308 | *Trifolium scutatum* | Boiss. | Leguminosae | برسيم | A | H |
| 309 | *Trifolium speciosum* | Sensu Boiss.et Griseb. Errat | Leguminosae | برسيم | A | H |
| 310 | *Trifolium spumosum* | L. | Leguminosae | برسيم | A | H |
| 311 | *Trifolium stellatum* | L. | Leguminosae | برسيم نجمي | A | H |
| 312 | *Trifolium subterraneum* | L. | Leguminosae | برسيم تحت ارضي | A | H |
| 313 | *Trifolium tomentosum* | L. | Leguminosae | برسيم صوفي | A | H |
| 314 | *Trigonella filipes* | Boiss. | Leguminosae | حلبة خيطية | A | H |
| 315 | *Trigonella kotschyi* | Fenzl ex Boiss. | Leguminosae | حلبة كوتشي | A | H |
| 316 | *Trigonella monantha* | C.A.Mey. | Leguminosae | حلبة احادية الزهر | A | H |
| 317 | *Trigonella monspeliaca* | L. | Leguminosae | حلبة | A | H |
| 318 | *Trigonella noaeana* | Boiss. | Leguminosae | حلبة | A | H |
| 319 | *Trigonella spicata* | Sm. | Leguminosae | حلبة سنبلية | A | H |
| 320 | *Triticum durum* | Desf. | Gramineae | قمح قاسي | A | H |
| 321 | *Valantia hispida* | L. | Rubiaceae | | A | H |
| 322 | *Valerianella coronata* | (L.) DC. | Valerianaceae | خس تاجي | A | H |
| 323 | *Valerianella echinata* | (L.) DC. | Valerianaceae | | A | H |
| 324 | *Valerianella pumila* | (Willd.) DC. | Valerianaceae | خس قزم | A | H |
| 325 | *Valerianella vesicaria* | (L.) Moench | Valerianaceae | خس مثانية الثمرة | A | H |
| 326 | *Velezia rigida* | L. | Caryophyllaceae | | A | H |
| 327 | *Verbascum gaillardotii* | Boiss. | Scrophulariaceae | بوصير | B | H |
| 328 | *Verbascum sinaiticum* | Benth. | Scrophulariaceae | بوصير سينائي | B | H |
| 329 | *Verbascum transjordanicum* | Murb. | Scrophulariaceae | بوصير | B | S-Sh |
| 330 | *Veronica persica* | Poir. | Scrophulariaceae | زهرة الحواشي الفارسية | A | H |
| 331 | *Veronica polita* | Fries | Scrophulariaceae | زهرة الحواشي الرمادية | A | H |
| 332 | *Vicia cuspidata* | Boiss. | Leguminosae | بيقية منقارية القرن | A | H |
| 333 | *Vicia hybrida* | L. | Leguminosae | بيقية مهجنة, بيقية صفراء | A | H |
| 334 | *Vicia palaestina* | Boiss. | Leguminosae | بيقية فلسطينية | A | H |
| 335 | *Vicia sativa* | L. | Leguminosae | بيقية مزروعة | A | H |
| 336 | *Vitis vinifera* | L. | Vitaceae | عنب بلدي جعفري | P | C-T |
| 337 | *Vulpia ciliata* | Dumort. | Gramineae | | A | H |
| 338 | *Vulpia myuros* | (L.) C. C. Gmel. | Gramineae | | A | H |
| 339 | *Ziziphora capitata* | L. | Labiatae | نعينع | A | H |

**Biotype:** H: Herb, H-Sh: High Shrub, S-Sh: Sub-Shrub, T-T: Tall Tree, S-T: Small tree, T: Tree, C-Sh: Climber-Shrub, C-T: Climber-Tree
**Life form:** B: Biennial, P: Perennial, A: Annual.

# The Role of Networks in Non-Wood Forest Products and Services Marketing in Europe

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## Abstract

Starting from the evidence that some managers and owners are shifting from a timber-based activity to a Non-Wood Forest Products and Services (NWFP&S) based activities, the paper studies the key factors affecting NWFP&S marketing.

Products and services are classified in three main categories: mass-produced, specialized and complementary NWFP&S. This latter category can play a relevant role in improving the profitability and in maintaining the competitiveness of small and medium-scale enterprises involved in NWFP&S production and commercialization.

Differentiation, integration, and networks creation (among both private and public actors) with the development of "territorial marketing" are considered fundamental tools for strengthening the role of complementary NWFP&S in improving the economic value of small-scale forestry in marginal areas.

A description of three main network types that could be identified with regard to NWFP&S is then provided on the basis of the results of the study carried out in Italy with seventeen case studies.

Key factors of network development (e.g. need of clear property rights regulations, trust, equitable profit distribution, social capital, etc.) are then discussed shortly.

*Keywords: mass; specialized and complementary NWFP&S; territorial marketing; networking*

## The Importance of NWFP&S in Europe

Traditional and new Non-Wood Forest Products and Services (NWFP&S) experienced a growing interest throughout all of Europe during the last 20 years (Mantau et al. 2001). This is caused by the fact that they can greatly contribute in improving the profitability of forest-based enterprises and in maintaining the competitiveness of forest product-consumer chain.

**Table 1.** Average economic values of benefits from Mediterranean forest areas (€/ha/year).

| Mediterranean areas | Wood | NWFP | Grazing | Recreation | Hunting | Total | TEV[a] |
|---|---|---|---|---|---|---|---|
| Southern | 12 | 4 | 32 | n.a. | - | 48 | 67 |
| Eastern | 22 | 5 | 10 | 1 | 1 | 39 | 48 |
| Northern | 67 | 16 | 10 | 32 | 3 | 128 | 176 |
| Total Mediterranean | 47 | 12 | 13 | 21 | 2 | 95 | 133 |
| Share of total (%) | 49.5 | 12.6 | 13.7 | 22.1 | 2.1 | 100 | - |
| Share of TEVa (%) | 35.3 | 9.0 | 9.8 | 15.8 | 1.5 | 71.4 | 100 |

a: TEV = Total Economic Value
Source: adapted from Merlo and Croitoru (2005, p. 62).

Three main reasons of this interest can be identified: (a) the decreasing prices of wood products; (b) the growing demand for environmentally friendly products and products connected with some specific local traditions; (c) policies supporting rural development.

In relation to timber prices development, the United Nations Food and Agricultural Organisation (FAO) and the Economic Commission for Europe (UNECE) price databases' (UNECE/FAO 2007) show that real prices of industrial roundwood have been gradually decreasing in the last 20 years. Moreover, all major forecasts made by FAO and UNECE predict a constant decrease in real prices of wood products in the next few years.

Demand for environmentally friendly products is increasing in all highly industrialised countries (Lober and Misen 1995; Burrows and Sanness 1998). Many traditional products that were once strictly connected to the needs and consumption behaviour of low-income people are now regarded as natural health products (Meadley 1989; FAO 1995). Some 'specialty' foods and other forest products experience greater demand than in the past as a consequence of new fashions (e.g. 'Mediterranean diet', organic farming, natural medicine, aroma-therapy) (Pettenella et al. 2006).

Finally, the reform measures for the Common Agriculture Policy (CAP) have been promoting the diversification of rural activities and new sources of non-agricultural income in European Union (EU) member countries.

As a result, nowadays, even in some high productive forest areas traditionally managed for wood production, selling of recreational services (e.g. mushrooms collection permits) represents often a much more relevant source of income for the forest managers than timber sales. Commodities that once used to be considered "secondary products" are frequently the primary source of revenue for forest managers and owners (Merlo and Croitoru 2005).

Especially in Mediterranean areas, NWFP&S play a remarkable role both in relation to commercial objectives and in terms of estimated Total Economic Value (TEV) of forests, as reported in Table 1. While wood and grazing are declining sources of income for forest owners, tourism and non-wood forest products are increasing in importance to support rural life, mainly in higher income countries (Pettenella et al. 2007b).

Actually the development paths related to NWFP&S marketing are not homogeneous all around Europe and it is worthwhile to observe how obstacles to successful marketing have been overcome in different local contexts. To improve and consolidate the economical role of NWFP&Ss marketing strategies based on effective coordination among different rural products and services should be applied. We will try to demonstrate that networks among local resources managers are playing a key role in many successful examples of NWFP&S marketing.

**Table 2.** Examples of NWFP&S classified into mass, specialized and complementary categories.

| NWFP&S type | Products | Services |
|---|---|---|
| Mass-produced | Foliage (IRL)<br>Christmas trees (DK)<br>Moss (UK)<br>Mushrooms (POL, LIT and H)<br>Berries (FIN)<br>Chestnuts (I, CH)<br>Cork (P) | Picknicking (IRL and ISL)<br>Water protection (GER)<br>Nature conservation (A)<br>Hunting (LIT, ROM)<br>Recreation (CRO) |
| Specialized | Birch sap (FIN)<br>'Chemical free' Christmas trees (GER)<br>Chestnut specialities (CH, I)<br>Truffles (I)<br>*Pinus mugo* oil (I) | Bird watching (FIN)<br>Skiing (GER)<br>Funeral tree services (CH, GER)<br>Environmental Education (H)<br>Art in the Forest (I)<br>$CO_2$-sequestration (ROM) |
| Complementary | Truffles and tourism (I and CRO)<br>Chestnut, wine and rural tourism (I)<br>Ecotourism (H and IRL)<br>Mountain biking (UK)<br>Country holidays (NOR and LIT)<br>Biking tours (FIN)<br>Recreation park services (ROM and IRL)<br>Recreational services (DK) | |

Source: Jáger (2005).

## A Conceptual Framework for NWFP&S Classification

In this paper the role networks serve in the development of NWFP&S marketing will be analyzed on the basis of three main different NWFP&S categories (mass-produced, specialized and complementary) that will be shortly defined below.

In marketing literature (Kotler et al. 1996) a classic distinction is made between two types of target markets: mass markets and specialized markets. When considering NWFP&S a third market category (namely complementary NWFP&S) should also be added. Products and services included in this category are characterised by a joint demand of goods from users, a demand that can also involve some products or services not originating from forests. To give an example, in Table 2 are reported some NWFP&S' classified according to this broader framework developed by the Working Group 3 (WG3) of the COST Action E30 'Economic integration of urban consumers' demand and rural forestry production' (http://www.joensuu.fi/coste30).

*Mass Products and Services:* many traditional NWFP&S (e.g. cork in Portugal, *Botetus* mushrooms in Italy, Christmas trees in Denmark, bilberries in Finland) are undifferentiated and their target market is made up of a large number of consumers. They usually experience a very high competition and their markets are frequently over-supplied. Being characterized by a limited differentiation, products can only compete on price (Collier et al. 2004) and, in the Marketing Mix, cost minimization is a factor of fundamental importance (Figure 1).

Several forest services provided to a large number of users (water cycle regulation, soil protection, biodiversity conservation, $CO_2$ sequestration, supply of recreational sites) are free of charge and accessible to everybody. Introducing payments mechanisms for such

| | **Mass** | **Specialized** | **Complementary** |
|---|---|---|---|
| **4 Ps** | *Product*<br>*Place*: logistic, etc.<br>***Price*: cost minimization**<br>*Promotion* | ***Product*: quality assurance, certification, packaging, links with a territory and/or a local tradition, etc.**<br>*Place*: logistic, etc.<br>*Price*: selling system<br>***Promotion*: e-marketing** | ***Product*: strong links with a territory and/or a local tradition, "baskets" of different products and services, etc.**<br>*Place*<br>*Price*<br>*Promotion* |
| **2 Ps** | *Political power*<br>*Public support/ participation* | *Political power*<br>*Public support/ participation* | *Political power*: partnership (Leader approach)<br>***Public support/ participation*: social capital (i.e. capacity to cooperate among private and public actors)** |

**Figure 1.** Marketing Mix of mass, specialized and complementary goods.

forest services is becoming an interesting field of development for mass services, in Europe (Mantau et al. 2005) and worldwide (Pagiola et al. 2002).

In the mass products supply chain, especially in larger scale operations, middlemen (marketing companies, buying groups and wholesalers) are usually involved in selling systems. Some producers introduced vertical integration as a means to attain greater control of product quality (e.g. cork producers in Portugal), in other cases horizontal integration among growers or producers has been implemented by the creation of associations or informal networks. This strategy can improve the value of NWFP&S business activities through the use of standards, brands and trademarks for promoting the products on the international market (e.g. the case of chestnuts in Italy, reported by Pettenella et al. (2005)).

Some key factors concerning successful marketing of mass NWFP&S that can be identified are:

- Human resources and social capital, because the availability of adequate number of qualified people is usually a problem in rural, marginal areas. Personnel may need to be trained, or persons from outside the area will need to be adequately motivated to move in and to stabilize the local business;
- Climatic conditions and disease outbreaks, which can potentially devastate yields;
- Seasonality (some NWFP&S are available and have to be harvested and sold over only a short period of time);
- Perishability of products: rapid delivery channels, appropriate storage facilities and processing are needed.

*Specialized Products and Services:* they are well differentiated products and services, often with a high added value and available in relatively limited quantities. Since they are typically

**Box 1.** Different set of standards used for NWFP certification and labelling.

Some standards that are actually used as differentiation tools for specialized NWFP&S are:

- sustainable forest management and chain of custody standards, such as the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC);
- standards to protect the origin, such as those define by the European Commission Regulation 2081/92: the Protected Designation of Origin (PDO) and the Protected Geographical Indication (PGI);
- standards for organic wild products such as those defined by International Federation of Organic Agriculture Movements (IFOAM) or by the European Commission for organic crops cultivation (EC Regulation 2092/91);
- standards for collecting, processing and marketing biological resources defined by the UNCTAD BioTrade Initiative;
- standards for fair trade defined by Fairtrade Labelling Organizations (FLO).

Some examples of certification and labelling are:

- FSC certified Christmas trees from Switzerland and Lithuania; oak tree bark, greeneries from Denmark; cork in Portugal;
- PEFC certified aromatic essence from Pinus mugo in Italy;
- In Italy a forest area producing mushrooms (Boletus edulis) has been registered as a PGI product and some chestnut proveniences have been certified both under the same scheme and as organic products according with the EU rules.

Certification systems have been developed also for some forest environmental services, e.g. the Carbon storage certification standards related to forest investments developed by Société Générale de Surveillance (SGS) and by Det Norske Veritas (DNV), and the Sustainable Tourism Management standards developed by Rainforest Alliance.

targeted to small customer groups, segmentation and correct customer information are very important tools to develop their markets.

Two types of enterprises active in this NWFP&S category can be identified:

1) small- and medium-sized enterprises (SME's) with limited financial and labour resources, normally working only in the forestry sector, which are specialized on small-scale activities (e.g. adventure or canopy forests in France, forest museums in Italy or funerals and "ecological burial" services in Switzerland and Sweden);
2) large enterprises, not necessarily working only in the forestry sector, producing or selling a large range of goods, including some specialised products and services (e.g. 'chemical free' Christmas trees in Germany).

Differently from mass NWFP&S, many specialized products are "new" products (e.g. adventure forest parks, "ecological burials") or traditional rediscovered products, which were already almost forgotten or out of commercial use for a long time (e.g. "*manna*" sap from ash trees in Italy, *Erica arborea* roots for pipe making in Albania or birch sap in Finland).

In the Marketing Mix of specialized NWFP&S an important role is played by the factors "Product" and "Promotion" (Figure 1). With respect to "Product", quality assurance and standardisation, further developed into various certification schemes, labels and brands, are very important product differentiation tools that give the possibility of premium prices (Box 1). For specialised NWFP&S marketing, special attention must be paid to "Promotion": they must reach the defined target groups, under the constraint of a limited investment potential by the forest managers. E-commerce (both B2T and B2C) is becoming an extremely useful instrument for marketing specialized NWFP&S.

Despite the use of certification and labelling systems, specialized non-wood forest services remain problematic because of two main reasons: a single, transparent, credible and well-known identification mechanism does not exist for them; in some cases there is a high risk of imitation by competitors (e.g. forest adventure parks, environmental education courses).

A fundamental pre-requisite for developing many new markets for NWFP&S is the implementation of a proper regulation on property rights: in many countries a free access regime to the forest resources is limiting new investments in NWFP&S.

*Complementary Products and Services:* they consist of products and services that can be sold and used in strict association because of important synergies connected to their joint marketing. Not all products and services that are jointly marketed have to necessarily be originated from forests (e.g. the "*Törggelen*" holidays: Autumn holidays organized in the Italian South Tyrol during which tourists can walk in chestnut orchard, pick up the nuts and then eat the roasted chestnuts in agri-tourist farms while tasting the new red wines).

Complementarity is a concept related to the different linkages that can connect products and services. Complementarity products and services are an advanced form of network. Networks can be defined as "a mode of organization that can be used by managers or entrepreneurs to position their firms in a stronger competitive stance" (Carlos Jarillo 1988).

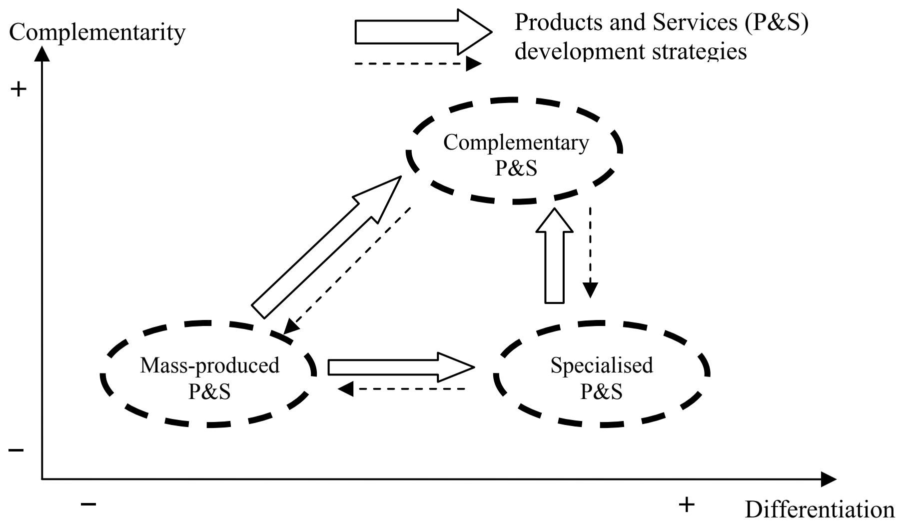
It is possible to differentiate networks according to two main variables: time and place.

With respect to time, "opportunistic" or "strategic" networks can be defined. The first one can be described as short-term network: a temporary set of links established among managers or enterprises that last, for example, only for the time needed to develop a common special marketing project. The second one, instead, is characterized by long-term relationships, and can be described as "purposeful arrangements among distinct but related organizations that allow those firms to gain or sustain competitive advantage vis-à-vis their competitors outside the network" (Carlos Jarillo 1988).

With respect to place, "not territory-based" and "territory-based" networks can be identified. The first ones are composed of units that act together independently from their action area because they share a common field of action, a goal, etc. (e.g. a regional associations of beekeepers or and association of truffle pickers). The second ones, instead, have a specific territory[1] as "common denominator". This is the field of interest of a new branch of marketing, the so-called "territorial marketing". According to this concept, a whole consistent portfolio of products and services strictly linked with the environmental, social or cultural characteristics of a territory is developed. Despite the fact that the enterprises involved in the network work in different fields, they interact to develop a consistent portfolio of products and services and they bundle marketing efforts for their coordinated promotion. Common tools used to connect the various products and services offered by a territory are organised trails, roads or pathways linking farms, craftsman shops, restaurants, exhibitions, monuments, fairs and cultural events.

In general terms, when looking at the Marketing Mix (Figure 1), it can be observed that the leading role is played by the "Product" factor, but in a different way than for specialized ones.

1 Some examples of homogeneous territories that can be defined (with examples for Italy) are: a valley or a watershed or the area around a mountain group; a National Park or other types of protected area; an area traditionally linked to a specific product or service (e.g. the Alba territory connected to white truffles); and a forest itself (e.g. the Black Forest in Baden-Wurttemberg).




Source: adapted from Pettenella et al. 2006

**Figure 2.** NWFP&S marketing development strategies.

In this case a diverse strategy for differentiating goods is used. It consists in the development of a “basket” of various goods that are marketed and sold together. The other attribute characterizing complementary products and services is the “Public support/participation” factor. It refers to the cooperative attitude among private and public actors, which share a common vision and are able to carry on coordinated economic initiatives. This competitive advantage is named, in the terminology of social scientists, “social capital”.

NWFP&S’ can change their target market: a specialized product can develop into a mass product or into a complementarity product (and vice versa), as shown in Figure 2. A common development path from a mass product into a specialized product and then into a complementarity product is described by Figure 3.

As reported in Figure 3, the development from one or few enterprise dealing with mass NWFP&S marketing to a group of enterprises involved in complementary NWFP&S is due the creation of trust-based relationships. This evolution takes place in two different forms: through consolidation (of links, relationships, etc.) in the first step, from mass to specialized NWFP&S, and through “contractualization” in the second step, from specialized to complementary NWFP&S. While in the first case connections are strengthened either in a vertical (along the value chain) or in a horizontal (similar enterprises, etc.) direction, but usually without formal agreements, in the second case relationships rely on a basis of contracts and formal, more stable, agreements. In a parallel way, the role of territory becomes more and more relevant going towards complementary NWFP&S, this being the most common basis on which networks develop.

From the perspective of the policy maker promoting a stable and progressive policy of rural development, complementary goods are of primary importance; actually their role in local rural development is by far higher than the commercial value of the single products or services that compose them.

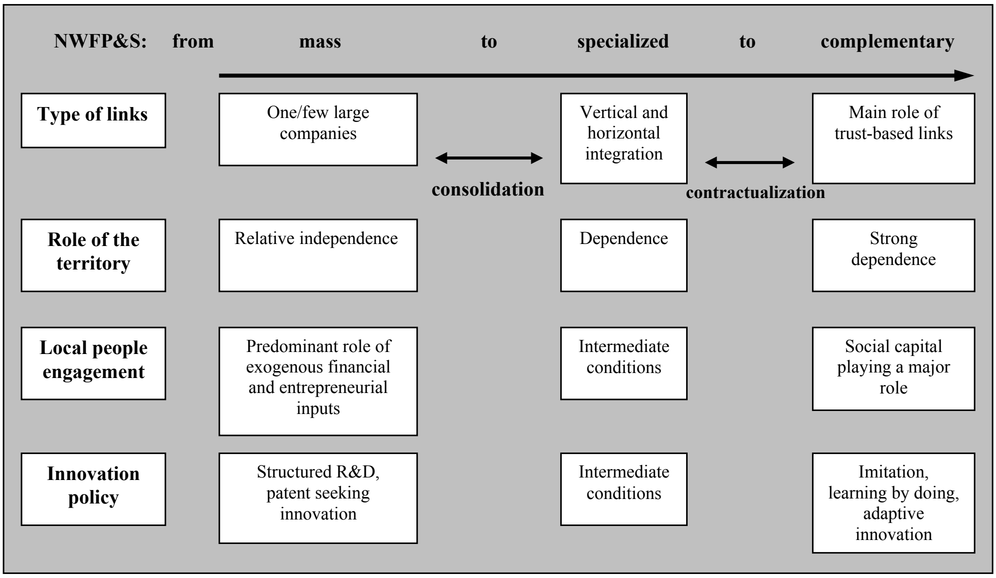



**Figure 3.** The development steps from mass to specialized to complementary NWFP&S.

## The Role of Networks in Complementary NWFP&S: Three Network Typologies

Based on the case studies of the COST Action E30 (Pettenella et al. 2006) and on a further analysis of 17 Italian case studies (Pettenella et al 2007a), three main typologies of networks linking NWFP&S to other products and services have been identified (represented graphically in Figure 4).

(a) In the first case the NWFP&S is usually a non-marketed good, generally provided free of charge by local authorities (e.g. concerts organised in the forests, cross-country skiing trails, open-air museums). The aim is the attraction of consumers that, once in the territory, will enforce other economic activities (e.g. restaurants, shops selling typical local products, etc.). The costs of providing the non-marketable NWFP&S can be covered by public authorities or by the beneficiaries of associated commodities sold in the territory.

    As Figure 5 shows, the activity is usually concentrated on few months (e.g. the summer season for concerts and open-air museums, winter for cross-country skiing trails). The level of investment (public or even private) concentrates on the period of the activity and slightly before, since it consists of the promotion and of the funding of the activities.

(b) In the second case the NWFP&S is a marketable good that takes advantage of synergies deriving from joint promotion and selling with other products and services of the same territory. Advantages deriving from joint promotion consist of consequent higher volumes of sales, increased number of clients and profit levels. Some examples are: mushrooms or berries picking permit sales, ‘Chestnut roads’ where the purchasing of chestnuts is associated with tourism and consume of other products (e.g. wine of the

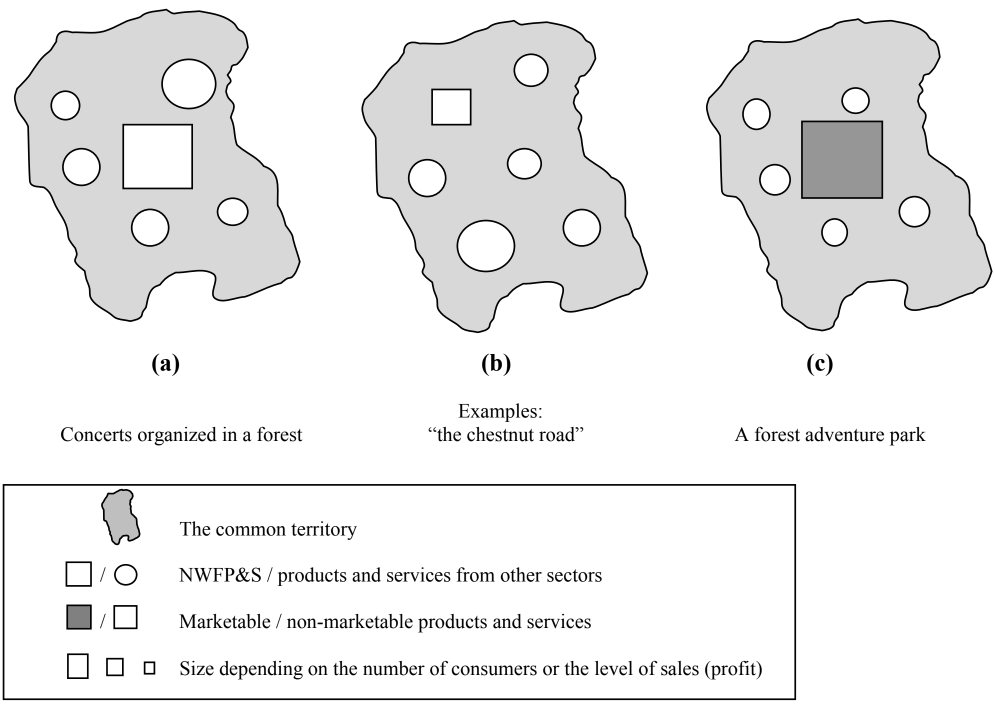



**Figure 4.** Marketing development strategies applied to complementary NWFP&S.

same area), etc. For example, in the case of mushrooms (figure 6), the level of public investment can be close to zero, as activities are usually self-financing. The activities are multiple and concentrate more or less between late spring and the beginning of autumn. Two peaks can be individuated in concomitance with the spring and autumn productive seasons. Other activities are then added with the purpose of reaching a constant customers' presence during a larger time period. If seasonal production attracts mushrooms pickers (buying picking permits), other activities (such as fairs and trails) are organized to attract the broader public to the area, which will stimulate other related economical activities (as explained for the case (a) described before).

(c) Finally, in the third case, the NWFP&S is a leading marketable good offered in a territory, and there are other products and services from the same territory complementing and supporting it. An example is that of the "forest adventure parks" where the leading service is the adventure park and the usually associated service is an equipment hire, or a bar or a gadget shop. The marketable good is the attraction factor and it is self-financing. Moreover, it stimulates the development of other economic activities by creating a new demand and by increasing the potential customers for other more or less related goods.

Looking at Figure 7, it can be seen that these kind of NWFP&S do not require public investments and that the level of activity is seasonal, both for the main good (e.g. the adventure park) and for associated ones. It usually lasts from late summer to early autumn, according to climatic conditions.

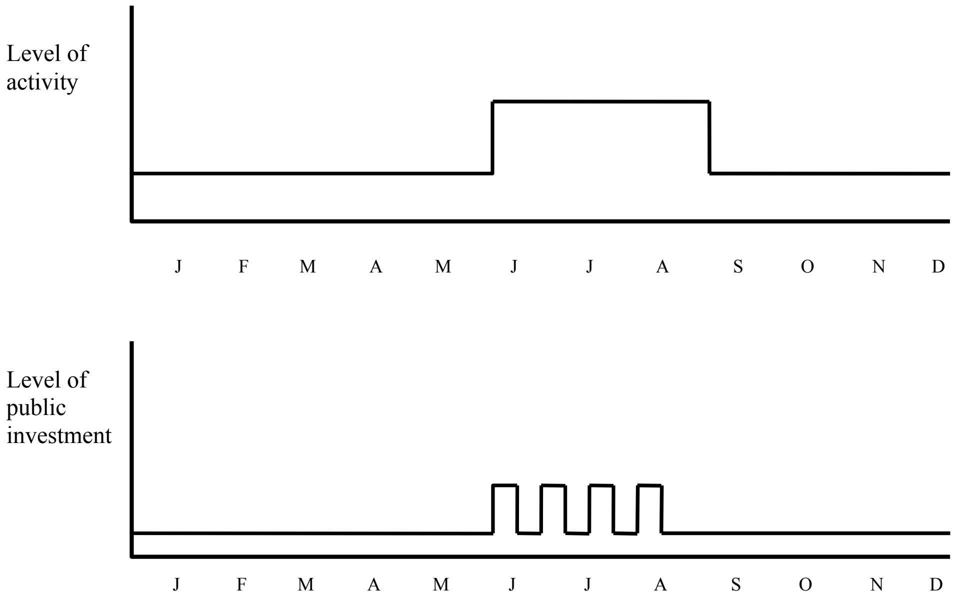



**Figure 5.** Level of activity and of public investment in (a) type NWFP&S.

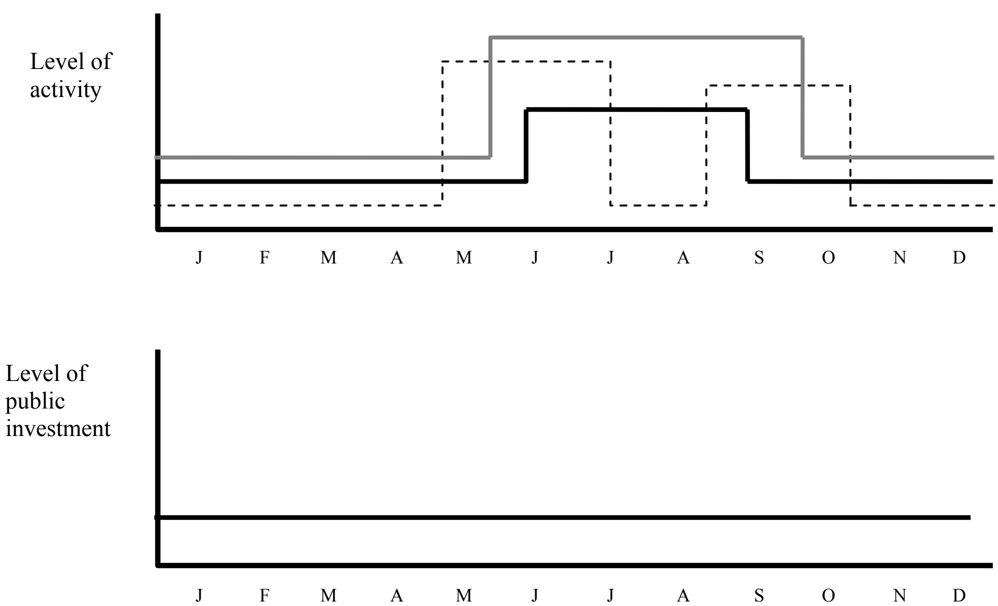



**Figure 6.** Level of activity and of public investment in (b) type NWFP&S.

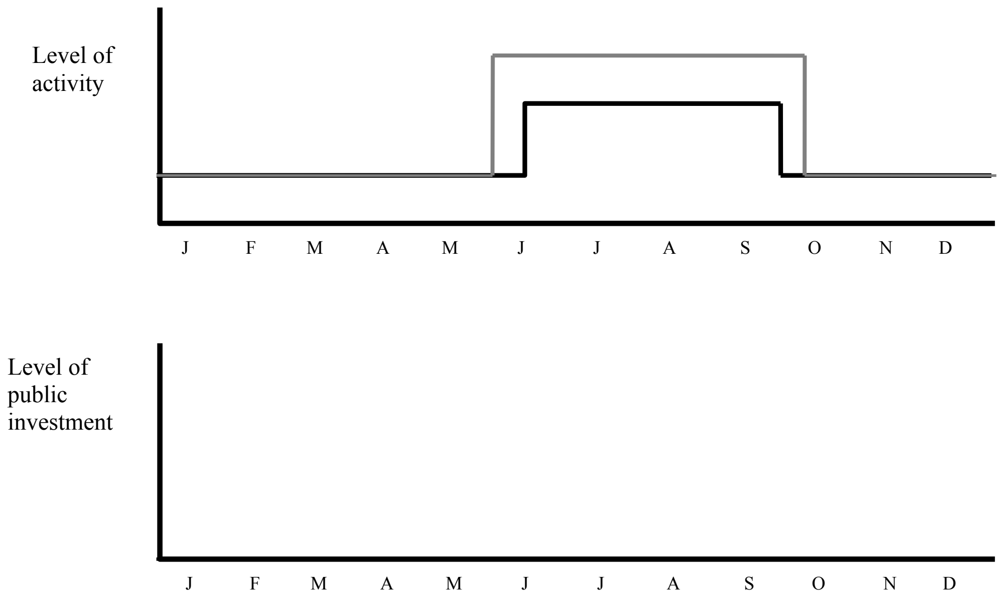



**Figure 7.** Level of activity and of public investment in (c) type NWFP&S.

The creation of a portfolio of related products and services in a clearly delimited territory offers many advantages, especially when SME's are involved. In fact the joint marketing strategy needed by the portfolio allows to overcome the limited financial resources and competences in promotion techniques of the individual SME's.

Moreover, complementary services or products can help to add value or competitive advantages to the main product, diversifying its nature or its image, so that it can be targeted to new customer groups. In territorial marketing NWFP&S play an interesting role as 'imago' products (i.e. a simplified and symbolic brand of the territory). Even when their role in the portfolio is minor, they are often used as a brand to present the territory, being among the most environmentally-friendly products.

Joint marketing frequently stimulates a positive co-operation between private operators and local public authorities as well as between landowners and services providers. Clear agreements on costs and benefits for each actor, responsibilities sharing, trust and open exchange of knowledge are needed in the production, processing and marketing channels, both in private-public and private-private partnerships (including those between providers and subcontractors). In many areas we are far from reaching this level of coordination between the local actors (Box 2).

## Conclusions

The research carried out demonstrates that there are interesting opportunities for successful NWFP&S marketing, but also that some constraints exist.

**Box 2.** The results of a survey on coordination capacity in marketing NWFP&S.

A recent survey by Serbati (2007) carried out in Belluno province of Veneto region, in the area going from the National Park of Belluno Dolomites up to Natural Regional Park of Ampezzo Dolomites, showed that the enterprises producing and marketing NWFP&S are operating in a totally independent way one from the other. Forest managers having a riding school that organize horse rides in the forest and owning also a Bed and Breakfast activity in the same structure, do not have the intention of proposing packages putting together these services. Who owns a forest adventure park provide the equipment to rent as the only joint service. At most, he provides other services (e.g. sledge-dog or snow-shoe excursions) during the winter closure but there is no interest of establishing links with other possible providers of complementary products and services.

Production and commercialization of NWFP&S need clear regulations of property rights (Mantau et al. 2001) and, due to the large variety of products and services involved, this is a complex issue to be faced by local and national institutions (Marshall et al. 2006).

Mass-produced, specialised and complementary NWFP&S are not always clearly distinguishable one from another. In fact, complementary products and services can originate from mass products and services as well as from specialised ones. A mass product characterized by low added value and low market value can become a successful (complementary) product when combined with some specialised service. An example is the combination of the selling of raw material collected from nature, such as moss or twigs, with some handicraft courses. In the same way, complementary products can derive by highly specialised niche products that are not able to reach the critical mass of supply when commercialized independently and therefore need to be associated with other products.

When the production of mass NWFP&S is no longer profitable (in most cases because of high production costs) there are two possible strategies. One is based on differentiation, that is the transformation of the mass product or service into a specialized one. The other is complementarity, consisting in the transformation of mass or specialized products or services into complementary products and services. This aim is reached by combining NWFP&S with forest or non-forest services or products to offer, for example, packages of forest recreation plus tasting of forest specialities, or packages based on nut picking plus wine drinking and forest recreation.

The implementation of territorial marketing strategies is a key factor for the achievement of complementarity. Integration and, above all, network development among SME's, associations, public institutions, etc. play a fundamental role in this context.

Moreover, innovation in forest resources management should always be fully supported by the local community, the general public and the public authorities, especially in rural areas characterised by unique and fragile environments.

At present, even if successful cases of application of complementarity concept to NWFP&S exist in Europe, a lot of work still remains to be done in this field. In fact, these cases are limited both in the number of involved products and services, in the total economic value of businesses, in the actual development of networks and also in the creation and sharing of social capital. Another critical point is that concerning how the involved SME's can get the funds they need during the first phases of the jointed promotion of NWFP&S. In this phase the economical support by public authorities is always of utmost importance.

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# Estimating Above-Ground Biomass of Mirbeck's Oak (*Quercus canariensis* Willd.) in Kroumirie, Tunisia

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## Abstract

Monitoring forests in order to understand the impact of global climate changes on terrestrial ecosystems has become of great importance. In fact, to characterize forest changes, it is useful to parameterize a forest by using several parameters such as biomass, basal area, tree density, tree height, and trunk diameter at breast height. Ten trees of natural Mirbeck's oak (*Quercus canariensis* Willd. = *Quercus Mirbecki* Dur.), representative of the main diameter classes, were harvested from four sites in Kroumirie. Allometric equations were established for estimating tree above-ground dry-weight. Diameters at breast height (DBH) of felled trees ranged from 4.8 to 48.4 cm, total heights from 4.49 to 18.33 m and dry-weights from 5934 to 1989.069 kg. From these parameters, a number of biomass equations including trunk wood mass, trunk bark mass, branches wood mass, branches bark mass, twigs and buds mass, foliage mass and total branches mass were developed and tested statistically. Non-linear models based on trunk diameter at breast height (DBH) alone explained more than 98% of the biomass variation. Within all these parameters, strong site independent correlations were observed. Coefficients of determination ($R^2$) for the selected total biomass models ranged from 0.8996 to 0.9822. Equations for wood trunk biomass and foliage biomass have showed higher coefficients of determination than did equations for either bark trunk biomass, branches biomass, twigs and buds biomass or total branches biomass of these deciduous tree species

*Keywords: Kroumirie; Quercus canariensis Willd.; biomass; allometric equations*

## 1. Introduction

Forest biomass quantity is the result of the difference between production through photosynthesis and consumption through respiration, mortality, harvest and herbivory.

The rate at which forest biomass changes depends on several factors (i) direct human activity (silviculture, harvesting and clearing,…), (ii) natural disturbances caused by wildfire or pest outbreaks and changes in climate and atmospheric pollutants.

Forest biomass is known for its importance as a supply of fodder, feed and fuel (Rawat et al. 1988). It determines the potential amount of carbon that can be sequestered on the land when forests are well managed. This parameter is required as the primary inventory data to understand carbon pools changes and productivity of forests (Whittaker et al. 1971), is a useful measure for comparing structural and functional attributes of forest ecosystems across a wide range of environmental conditions (Brown et al. 1999) and provides valuable information for many global issues.

Debate is currently underway regarding how to evaluate the forest biomass which can be used to appreciate sequestered carbon and understand some of actual climate changes.

In Tunisia, many studies have been intended in this field for many species of pine but fewer were the studies that have dealt with oak species and no work was precompiled for Mirbeck’s oak.

Thus, characterizing the biomass amount and mechanism of carbon sinks in these natural Mirbeck’s oak stands became of great scientific, ecological, environmental and political importance.

The first aim of the present study was limited to the estimation of above-ground biomass of Mirbeck’s oak in the Kroumirie’s forests (North West of Tunisia), which spreads over 15 000 hectares.

## 2. Material and methods

### 2.1 Study sites

The study was carried out in eleven plots of Quercus canariensis stands located across the Kroumirie region. The plots are situated at four sites; Aîn Zana (AZ: 2 plots), B’ni Mtir (BM: 2 plots), El Feîdja (EF: 4 plots) and Oued Zeen (OZ: 2 plots). All sites are located in Jendouba governorate (Kroumirie Mountains, Jendouba (Tunisia) 40$^{G}$46‘-41$^{G}$N and 06$^{G}$48‘-07$^{G}$E), as shown in Figure 1.

### 2.2 Study site characteristics

The climate of the studied zone features rainy winters and warm summers and thus it was classified as being humid Mediterranean.

In all plots, in addition to the tree stratum comprising *Quercus canariensis* Willd., shrub stratum is present with spiny *Rosaceae* (*Rubus ulmifolius*, *Crataegus oxyacantha*, etc.), *Cytisus villosus*, *Erica arborea*, *Arbutus unedo*,…

As rainfall increased with altitude, *Agrimonia eupatoria* became more abundant whereas in clearing forest and lower altitude *Calycotome villosa* and *Cistus monspelensis* expand.

In the herbaceus stratum there is a predominance of *Poaceae* (*Cynosorus elegans*, *Cynosorus echinatus*, etc.) and *Urginea maritima.*

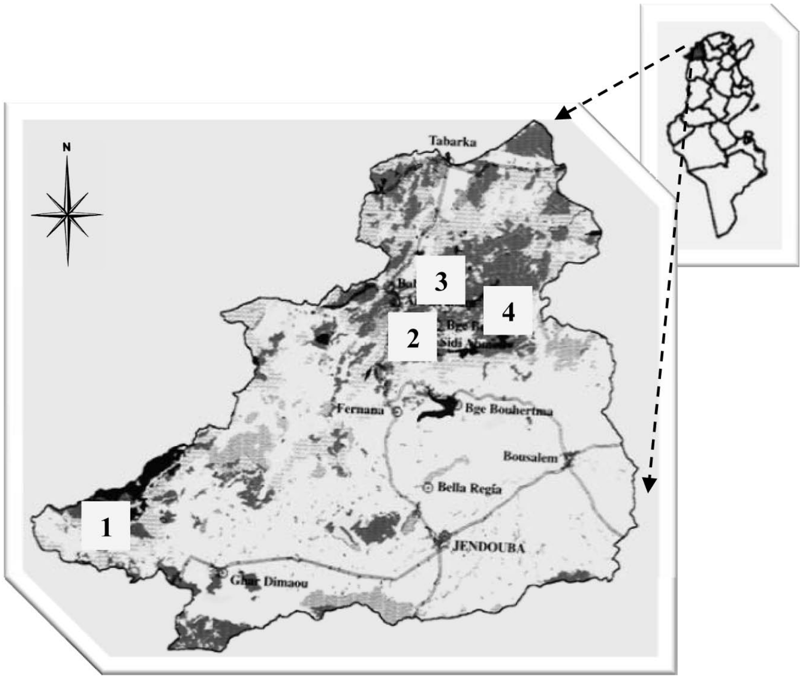


**Figure 1.** Localisation of the studied sites in the Kroumirie Mountains of Tunisia (1: El Feîdja, 2: B'ni Mtir, 3: Aîn Zana, 4: Oued Zeen).

All plots were developed over a sandstone substrate with insertion of clay banks.

The soil ranges widly in depth, eventhough it is classified as acid forest mull with a C/N ratio < 15 and a pH ranging between 4,5 and 5,6.

## 2.3 Biomass determination

The most common procedure for estimating biomass in forest stands is to use regression equations and stand tables, based mostly on DBH (DOBH at 1.3 m) and individual tree biomass. The DBH of all the stems on one ha (square shaped: 100 m × 100 m) in each of the 10 plots was measured and DBH classes were established. Ten Mirbeck's oak trees representing all DBH classes were felled and harvested. Each harvested tree was divided into bark (trunk and branches), wood (trunk and branches), twigs and buds and leaves.

Trunks were divided into sections and each section was weighed. Branches were separated from the trunk then weighed in the field, their basal diameters were measured. Leaves, twigs and buds and sometimes acorns, for aged trees, were separated from all harvested branches and weighed immediately.

Sub-samples of these different components were brought to the laboratory and over dried at 80 °C to a constant moisture for dry weight determination. Finally, allometric equations based on DBH and including wood mass, bark mass, twigs and buds mass and foliage mass were established by using and testing different regression models: linear and non linear.

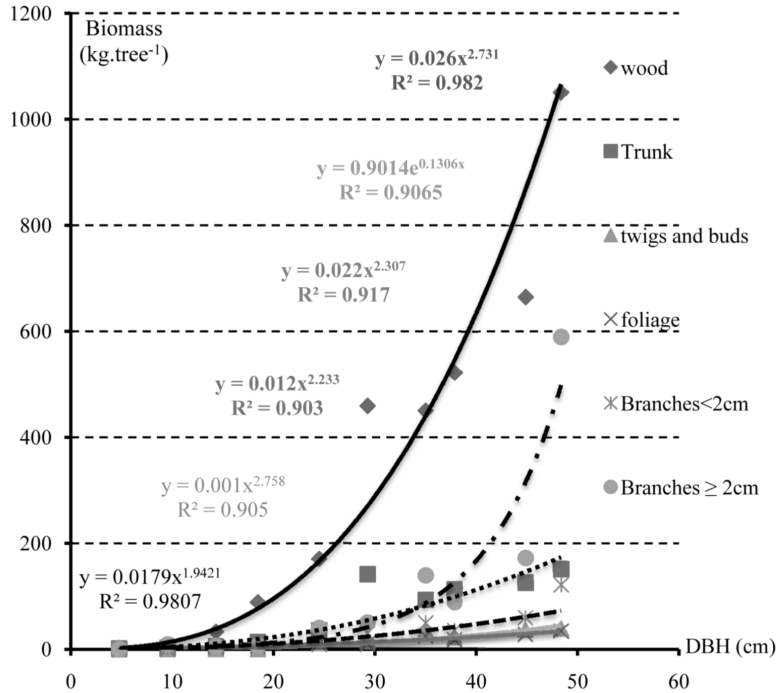


**Figure 2.** Relationships between DBH over bark and the different compartmental biomasses of harvested trees of *Quercus canariensis* in the Kroumirie region of Tunisia.

### 2.4 Statistical analysis

Statistical analysis was carried out using "Microsoft office Excel 2007" software. For each component the retained regression equation was selected for its higher determination coefficient.

## 3. Results

The different regression equations calculated for each total sub-sample biomass (Figure 2) and even for total biomass per tree (Figure 3) indicated best determination coefficients with power regression represented by:

**Y** = a **X** $^{b}$ that **Biomass** = a (**DBH**) $^{b}$

Only for the regression equation of branches whose diameter ≥ 2 cm (Figure 4), best determination coefficient was obtained with exponential regression represented by:

**Y** = a **e** $^{bX}$ that **Biomass** = a **e** $^{b\,(DBH)}$

Coefficients of determination ($R^2$) for the selected total biomass models ranged from 0.903 to 0.982 (Table 1);

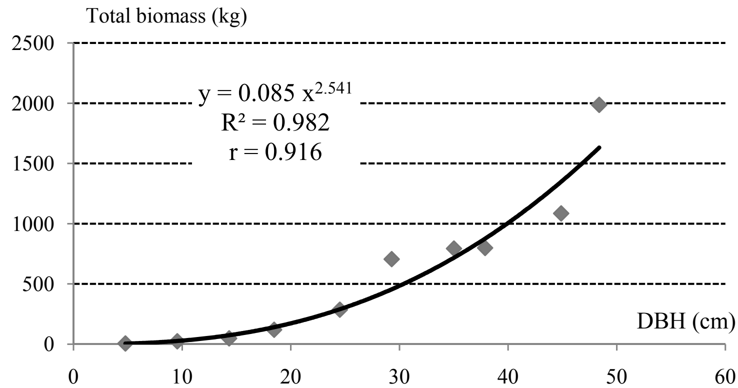


**Figure 3.** Relationship between Total biomass per tree and DBH.

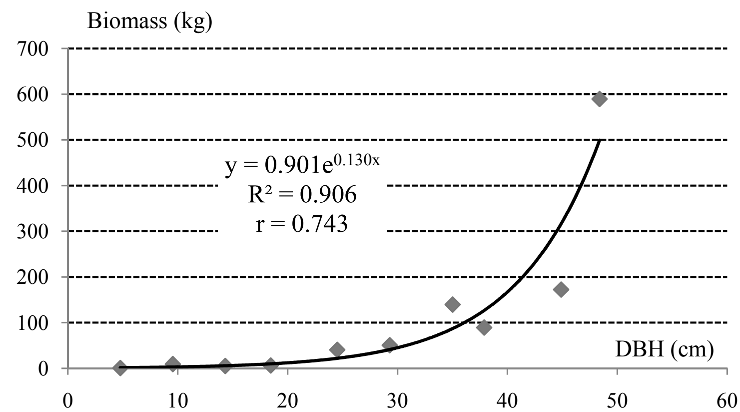


**Figure 4.** Relationship between biomass of Branches ≥ 2cm per tree and DBH.

Estimated mean total biomass per hectare (Table 2) showed variation between plots which may be due to (i) climate and soil characteristics of each plot, (ii) age, density and plot development conditions, (iii) low number of harvested trees, (iv) several anthropo-zoogenic behaviors.

Equations for wood biomass and foliage biomass have showed higher coefficients of determination than did equations for either bark biomass, branches biomass, twigs and buds biomass or total branches biomass of these deciduous tree species.

## 4. Discussion

This study presents regression models to evaluate the total biomass of trees in several different aged Mirbeck's oak stands, using one simple measurement (DBH). In fact, similar results were obtained between the biomass of the trunk and its DBH for *Betula aetnensis*

**Table 1.** Relationships between regression equations of different component biomasses (**Y** in kg) of harvested Mirbeck's oak trees and DBH over bark (**X** in cm).

| Tree Components | n | Equations | $R^2$ | r |
|---|---|---|---|---|
| Wood (trunk + branches) | 10 | $\mathbf{Y} = 0.026\ \mathbf{X}^{2.731}$ | 0.982 | 0.94406*** |
| Bark (trunk + branches) | 10 | $\mathbf{Y} = 0.022\ \mathbf{X}^{2.307}$ | 0.917 | 0.91185*** |
| Branches ≥ 2cm | 10 | $\mathbf{Y} = 0.901\ e^{0.130\ \mathbf{X}}$ | 0.906 | 0.74294*** |
| branches < 2cm | 10 | $\mathbf{Y} = 0.012\ \mathbf{X}^{2.233}$ | 0.903 | 0.874294*** |
| Twigs + Buds | 10 | $\mathbf{Y} = 0.001\ \mathbf{X}^{2.758}$ | 0.905 | 0.934594*** |
| Foliage (leaves) | 10 | $\mathbf{Y} = 0.017\ \mathbf{X}^{1.942}$ | 0.980 | 0.953613*** |

***$\alpha$=0.001

**Table 2.** Densities and mean total biomasses of different studied plots in Kroumirie (Tunis).

| Studied plots | EF | BM | AZ | OZ |
|---|---|---|---|---|
| Mean density per hectare (min–max) | 346 (092–519) | 350 (284–416) | 712 (629–794) | 222 (204–239) |
| Mean total Biomass ($Mg.ha^{-1}$) (min–max) | 267.912 (095.430–639.606) | 211.514 (185.551–237.477) | 242.702 (237.768–247.637) | 168.829 (157.077–180.581) |

Rafin. (Léonardi et al. 1994), *Quercus suber* L. (Sebei et al. 2001), *Fagus sylvatica* L.(Huet et al. 2004) and also for *Quercus pyrenaica* Willd.(Santa Regina et al., 2000), between DBH and total aerial biomass. Hence, the validity of the allometric equation is obviously limited to the variation range in the DBH class of trees included in the sample, which implies that the equations generated may be applied to the same species in all sites of the Kroumirie or even other regions (in Algeria), provided they show similar characteristics.

The calculated above-ground-biomass ranged from 168.829 to 267.912 $Mg.ha^{-1}$ (Table 2). This difference could result from density, age, site characteristics and plot development conditions (Lemée 1978).

The higher amounts of above-ground-biomass were obtained at El Feîdja site whereas the lower amounts were noticed at Oued Zeen site. This may be in relation to increasing precipitations with altitude:

| Sites | Altitude (m) | Rainfall ($mm.year^{-1}$) | Biomass ($Mg.\ ha^{-1}$) |
|---|---|---|---|
| El Feîdja | 850–900 | 1217 | 267.912 |
| B'ni Mtir | 650–700 | 1140 | 211.514 |

Compared with some others species of oak in the Mediterranean basin, Mirbeck's oak has an above-ground-biomass higher than that found by (i) Sebei et al. (2001, 2004 et 2008) in Tunisian forests for cork oak (*Quercus suber* L.) and (ii) Rapp et al. (1999) in Spanish and French forests for two deciduous oaks (*Quercus pyrenaica* Willd. and *Quercus lanuginosa* Lamk.) and two evergreen oaks (*Quercus ilex* L. and *Quercus rotundifolia* Lamk.).

**Table 3.** Comparison of above-ground biomasses for oak species in the Mediterranean basin.

| Oak species | Country | Above-ground-biomass (Mg. ha$^{-1}$) | References |
|---|---|---|---|
| *Quercus pyrenaica* Willd. | Spain | 63.8–130.8 | Rapp et al. (1999) |
| *Quercus lanuginosa* Lamk. | France | 63.7 | Rapp et al. (1999) |
| *Quercus ilex* L. | France | 71.4 | Rapp et al. (1999) |
| *Quercus suber* L. | Tunisie (Kroumirie) | 48.9–234.2 | Sebei et al. (2001 and 2008) |
| *Quercus suber* L. | Spain (Saint Hilari) | 328 | Robert et al. (1996) |
| *Quercus canariensis* Willd. | Tunisie (Kroumirie) | 168.8–267.9 | present study |

Nevertheless, Robert et al. (1996) have showed a much higher estimated aboveground phytomass for the cork oak trees at Saint Hilari in Spain (Table 3).

Other methods can be used to estimate the amount of biomass in forest trees. Brown and Lugo (1984) have used stem volume to calculate biomass in tropical forests.

This methodology did not include biomass of other aboveground components and needs a factor relating wood density which varies within trees as a function of age, site productivity, etc. and lead to estimation errors.

To calibrate and verify the efficiency of these other methods, allometric equations must be used, as they provide more accurate information about the existing biomass (Acosta-Mireles, 2002).

An important aspect worth considering is that allometric models developed in this study can be used in situations of similar plant communities to estimate the amount of biomass in a reliable way, due to the high determination coefficients obtained.

## 5. Conclusion

As a result of this work, we have managed to achieve one of our objectives. The work has provided for the first time a detailed database of total above ground biomass in Mirbeck's oak forests in the Kroumirie region. Such a database could be used to provide a more accurate determination of carbon biomass stocks in these forests and improve our knowledge about the quantitative and qualitative future of the carbon stocks in living Mirbeck's oak forests.

A complementary study is underway to: (i) estimate the different mineral element levels in the several components, thus to understand better the losses from the forest ecosystem and the returns of nutrients into the soil, (ii) estimate the Net Primary Productivity (NPP) in these deciduous forests.

## Acknowledgments

This work was made possible through the help and the collaboration of all the Kroumirie's foresters. Our most sincere thanks go to the General Forest Direction, Jendouba, Fernana and Aïn Draham Forest services. The English revision was done by Miss. Thouraya Maâzaoui.

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# Economic Evaluation of Forest Fire Prevention Programme in Catalonia, NE Spain

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## Abstract

In Catalonia forest fires have an important environmental, economical and social impact. Due to some extreme fire incidents in the past decade, the problems of forest fires have attracted significant attention in the media and amongst policy makers, leading to an increasing public concern. In the present study the welfare effect of the implementation of a program of additional forest fire prevention measures is estimated. The proposed program would diminish the average area of forests burnt per year and the severity of forest fires, expressed by tree mortality. A contingent choice method was applied to elicit the marginal values of two forest fire impact attributes (area burnt and dead trees). In addition, the respondents were also able to select the preferred prevention type, by selecting whether the majority of the work would be done by prescribed burning or by physical fuel reduction. The implications of the present study may be of interest to policy makers in supporting decision-making on fire prevention programs considering social preferences.

*Keywords: Catalonia; forests; contingent choice method; physical fuel reduction; prescribed burning; social valuation; fire prevention program.*

## Introduction

Catalonia is located in the north-east of the Iberian Peninsula. The majority of Catalonia is dominated by a Mediterranean climate, with cold and moist winters and dry and hot summers (Piñol et al. 1998). Additionally, approximately 61% of Catalonia is covered by forest and shrublands. The forests, occupying almost 38% of the territory, are dominated by different pine (e.g. *Pinus halepensis*, *P. sylvestris*, *P. nigra*) and oak (*Quercus ilex*, *Q. suber*, *Q. humilis*) species (Gonzalez 2006).

As in other parts of the Mediterranean region, one of the major environmental concerns is the occurrence of devastating summer wildfires which can cause serious ecological and economic damage. The number of forest fires and the area affected vary considerably from year to year (e.g. see EFFIS 2006). However, it seems that in the last decades the number of forest fire incidents slightly increased. The driving factors for such a development are manifold; e.g. changing climate conditions (Piñol et al. 1998), abandonment of rural areas, expansion of fast growing species that are highly inflammable, tourism growth and development of extensive wildland-urban interface areas (Xanthopolus et al. 2006). Therefore the problem of forest fires is attracting more attention, reflecting the increasing public concern for this issue.

The authorities try to cope with this problem by redesigning policies[1] and increasing the financial means, with the intention of increasing the efficiency of fire extinction and to reduce the occurring damages. For example, in 2006 the Spanish government increased the budged for prevention and extinction measures by approximately 10% when compared to the year before (MMA 2006, MMA2007). However, the financial means are still very low when compared to the damages caused by wildfires. According to the Spanish annual report on forest fires for 2005, the total damage caused by fires amounted to approximately 505 million €, while in the same year the total budged for forest fire related action was only 63.5 million €[2] (MMA 2006). Would it be worth to invest more money? Would such additional investments be supported by the society?

Another question is how to invest the money for fighting the forest fire problem. Most of the Mediterranean countries responded to the emerging wildfire problem by increasing their extinction potentials. In Spain, for example, in 2005 around 70% of the above mentioned budged, was devoted to extinction measures. Such an approach might help to reduce the burned area in a "mild" fire season, but might, because of fuel accumulation, lead to devastating fire events in more difficult seasons (Xanthopolus et al. 2006). Therefore more efforts should be directed towards fuel reduction measures. Several methods for fuel reduction exist. They can be broadly divided into physical removals of biomass and prescribed burning. Physical removals are widely applied in Southern Europe, while prescribed burning is still less known. In Spain, for example, prescribed burning is regulated and applied only in some regions (e.g. Andalusia), while in some others it is slowly getting introduced (e.g. Catalonia) or even totally banned (e.g. Madrid) (Xanthopolus et al. 2006).

Legal limitations, missing experience in its application, and significant restrictions regarding smoke management[3], liability issues and safety, are some of the main reasons that prescribed burning is not a standard fuel reduction approach in the Mediterranean region (Xanthopolus et al. 2006). In addition, most of the awareness raising and prevention campaigns were based on the paradigm that in a forest any fire is bad and dangerous. Therefore, forest managers are concerned that using fires for fuel management might provoke confusion or even protests of the local population. Would the society in the Mediterranean area accept the application of prescribed burning as a prevention method?

To answer the above stated questions the social preferences regarding forest fire prevention measures investments and the use of different fuel reduction methods should be explored.

According to our knowledge for the Mediterranean region only Riera and Mogas (2004) conducted a study estimating the social value of a program that would reduce fire risk. They applied a pure referendum method for evaluating from the social point of view the acceptance for a proposed program that would reduce by 50% the risk of forest fires in Catalonia. Their

1 For example in Spain (BOE 2005).
2 This amount does not include the budgets of the autonomous regions.
3 Smoke management are policies and practices applied for the prevention and mitigation of negative impacts of smoke produced by the application of prescribed burning (Hardy et al. 2001)

study showed that 63% of the sampled population would be willing to pay the estimated extra-cost of 6 € per person and year to finance the program.

Hence, it was decided to launch a study to explore (i) whether the public would be willing to contribute additional money to support a program that would reduce damages caused by forest fires and (ii) whether the society has any preferences how the program should be implemented. The study was conducted for the region of Catalonia in Spain.

Economic methods, such as choice experiments, contingent valuation method, hedonic pricing and others, were developed to evaluate the social value or desirability for a certain product or service (Manisfield and Pattanayak 2007). In this study the contingent choice method was used as the valuation methodology.

The next section of this paper describes the case study. Section three outlines the main results, while the last part of the paper discusses the main results.

## Methodology

### Stated Preference Methods

Different stated preference methods can be used for eliciting preferences for environmental goods. Over the last decade attribute-based methods have been developed (Louviere et al. 2000, Hanley et al. 2001). The three most popular approaches of these ABMs are: (i) Contingent ranking; (ii) Contingent rating, and (iii) Contingent choice. These valuation methodologies are consistent with the welfare economic theory (Unsworth and Bishop 1994, Holmes and Adamowicz 2003, Louviere et al. 2000, Bennett and Blamey 2001).

In this study the contingent choice method was applied. This method requires that respondents compare two or more alternatives simultaneously from a choice set and then choose their preferred alternative. This choice simulates the actual market behavior, such as choosing a brand of coffee from among brands with different attributes. The alternatives to choose from are described in a questionnaire that details the attributes to be considered, the changes in quantity or quality levels that may occur, and a proposed payment. This payment can be seen as a contribution towards obtaining a desired change or avoiding an undesirable one. In this way, more than one attribute of a product is taken into account at the same time.

Contingent choice is based on the random utility maximization model (RUM) (McFadden, 1973). This model assumes that the individual's utility is the sum of systematic (v) and random (ε) components and can be expressed as

$$U_j = v(x_j, p_j; \beta) + \varepsilon_j \tag{1}$$

where $U_j$ is the true, but unobservable, indirect utility associated with the alternative j, $x_j$ is the vector of attributes associated with alternative j, and $\varepsilon_j$ is a random error term with zero mean. The error term represents the influence on the individual's choices that are known to the individual, but unobservable to the researcher.

The probability (P) that an individual will choose the alternative j from a choice set containing competing alternatives can be expressed as:

$$P(j|C) = P(U_j > U_k) = P(v_j + \varepsilon_j > v_k + \varepsilon_k), \forall j \neq k \in C \tag{2}$$

where C contains all of the alternatives in the choice set. Most often the choice probabilities are estimated using the conditional logit model (McFadden, 1973). The regression model is then estimated using a maximum-likelihood approximation (Hensher and Johnson, 1981).

### Survey Scenario

Before asking the respondents to choose their preferred alternatives, the choice context or scenario should be explained. In this study the survey scenario explained that due to land abandonment and changes (e.g. collecting litter and fire wood) in the use of forests, the propagation and intensity of forest fires in Catalonia might increase in the future. Therefore the regional government proposes to implement additional forest fire prevention measures that would decrease the propagation and severity of forest fires in Catalonia. Furthermore, the scenario explained that the additional prevention activities would be implemented by fuel reduction. This reduction could be achieved by applying different methods (i) prescribed burning and (ii) physical reduction.

Propagation and intensity of forest fires were used as attributes to describe the effects of forest fires and of the application of prevention measures. These attributes were selected since rate of spread and fire intensity are two primary attributes of fire behavior and their prediction is crucial in achieving effectiveness in both wildfire control and application of prevention measures (Martins Fernandes 2001). However for the purpose of this study, these attributes had to be expressed in terms, which would be understandable to the general public.

Tree mortality was found to be a suitable attribute for expressing the fire intensity, since it can be related to fire behavior indicators such as intensity (Gonzalez et al. 2007). When tested in focus groups and in personal interviews it was found that tree mortality was clear and well understood by the participants. According to Gonzalez et al. (2007) the tree mortality in the past forest fires in Catalonia, was around 45%. Since no reliable estimates exist of the future development of this attribute, the above value was used to characterize the situation which may occur in 10 years time without the implementation of additional prevention measures.

In the case of fire spread it was decided to use the average forest area affected by fires per year. This attribute was already applied by Riera and Mogas (2004) in their study. They found that it was suitable and well understood by the respondents. To estimate a base line situation the average burnt area of forest per year in Catalonia was estimated. According to the fire statistic for the period between1968–2006, the mean number of hectares affected each year is around 11 000 or 1% of the total forest area of Catalonia (GENCAT 2007). Not to overestimate the future situation, it was decided to use conservative estimates of the development, of both attributes, during the next 10 years.

### Choice Sets

A contingent choice experiment consists of several choice sets, each containing two or more alternatives. The alternatives are represented by a set of attributes and each attribute can take one of several levels. In this study three attributes were used, namely: (i) burned forest area; (ii) tree mortality, and (iii) annual payment to finance the fire prevention measures.

Each attribute had four levels, as shown in Table 1. For the "business as usual" or *status quo* situation, it was assumed that no additional fire prevention measures would be applied. Therefore the levels for burned area and tree mortality were kept as in the current situation. For the case of applying additional prevention measures, the levels of area burned and tree mortality were estimated according to simulations conducted in other studies (e.g. Gonzalez 2006) and according to expert opinions. When tested in focus groups it was found that the attribute levels appeared realistic and plausible. Payment levels were determined after personal interviews and focus groups in which respondents stated the maximum amount they were willing to pay for different scenarios; the extra cost for the *status quo* option was set to zero.

Each combination of attribute levels constitutes an alternative. There were 27 ($3^3$) possible combinations or alternatives, excluding the *status quo* levels. These were randomly grouped

**Table 1.** The three attributes and levels used in the contingent choice exercise.

| Attribute | Description | Levels |
|---|---|---|
| Burned forest area | The average of burned forest area per year in 10 years time will be | 10 hectares per 1000 (status quo)<br>7 hectares per 1000<br>6 hectares per 1000<br>5 hectares per 1000 |
| Dead trees | The average percentage of dead trees in forests affected by fires in 10 years time will be | 45 dead trees per 100 (status quo)<br>30 dead trees per 100<br>25 dead trees per 100<br>20 dead trees per 100 |
| Payment | The required payment per person per year for an additional fire prevention program | 0 euros (status quo)<br>15 euros<br>30 euros<br>50 euros |

into blocks of 2+1 (*status quo*). Each compound block of three alternatives contained (i) the *status quo* alternative, (ii) the alternative where the majority of additional prevention measures would be conducted by prescribed burning and (iii) the alternative where the majority of additional prevention measures would be implemented by physical reduction of fuels. Three different choice sets were presented to each respondent and each of the surveyed individuals were asked to select the alternative they prefer the most within a choice set. Figure 1 reproduces a typical choice set.

## Application and Questionnaire

The population under study comprised 200 members of the general population in Catalonia. The strata followed the age and gender structure of the population according to the population data for the year 2006 (INE 2007). The interviews were conducted face-to-face at the respondent's residences in June 2007. The selection of the respondents followed a random route procedure to select a household, and then the age and gender quotas to select the particular individual in the household.

The first part of the questionnaire was devoted to the presentation of the attributes to be valued, and the way of payment and the consequences of it. The central part contained the choice exercise as well as some debriefing questions. The final part of the questionnaire was designed to collect some socio-economic data of the respondents.

In the introduction the questionnaire informed about the current average area of burned forest and tree mortality caused by forest fires in Catalonian forests. Further it showed the expected variation of these attributes in 10 years, if the current trend would continue and no additional measures would be taken. Next, the questionnaire informed that by implementing additional fire prevention measures, the future fire propagation and intensity levels could be modified. Three alternative levels, apart from the *status quo* option, were offered for each attribute (Table 1). To further familiarize the individuals with the possible levels of change, they were asked to select the most preferred level, regardless of the cost necessary to achieve it. In this way, it could be detected whether an attribute was considered as good or bad, and whether the choices to be made later were consistent. In the last part of the introduction, the

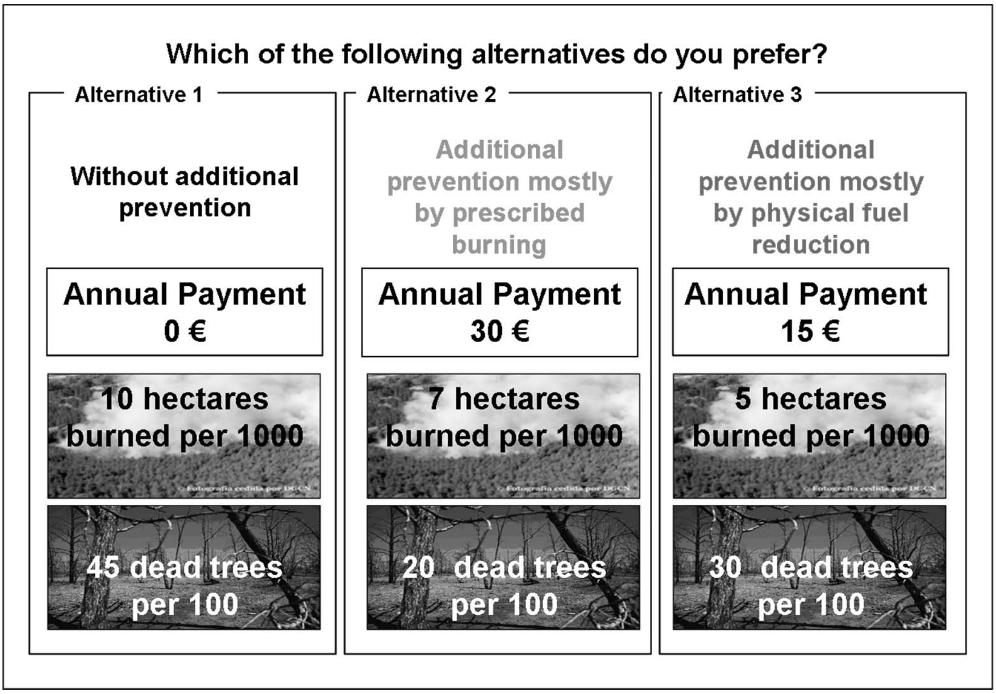


**Figure 1.** Example of a choice set presented to respondents in the contingent choice survey.

different prevention methods, namely prescribed burning and physical fuel reduction, were presented.

In the central part of the questionnaire, the monetary attribute was introduced. It was stated that the Catalan government was considering implementing an additional forest fire prevention program. The achievements of this program would depend on the amount of money devoted to it. The participants were told that the amount of resources would depend on their answers to the questionnaire. If on average the population would be willing to contribute an amount money to support the program, payments would be collected annually and indefinitely from the citizens, and the money given to a foundation to be created for this purpose.

Then the respondents were presented the choice sets and asked to select their preferred alternatives. At the end, this part also contained some debriefing questions.

Finally, the questionnaire inquired about the socio-economic characteristics of the respondent.

The questionnaire was administrated in paper and read by the interviewer. To better explain and present some of the topics, pictures and graphics were shown on separate cards. The average time of the interviews was approximately 15 minutes.

## Data Treatment

The regression analysis was completed by using NLOGIT 3.0 software (Green 2005) and SPSS version 15.0 statistical package (SPSS 2006).

**Table 2.** Results of the multi-nominal logit regression analysis.

| Attribute | Model I | Model II | Model III |
|---|---|---|---|
| Area burnt | -0.361*** [0.071] | -0.361*** [0.071] | -0.361*** [0.071] |
| Tree mortality | -0.334*** [0.079] | -0.334*** [0.079] | -0.334*** [0.079] |
| Annual payment | -0.422*** [0.074] | -0.422*** [0.074] | -0.422*** [0.074] |
| ASCSQ | - | -1.462*** [0.393] | -2.087*** [0.489] |
| ASCPB | 1.462*** [0.393] | - | - |
| ASCPR | 1.725*** [0.353] | 0.266**[0.112] | -0.345 [0.310] |
| NOPB | | | 0.507** [0.243] |
| Log L | - 377.99 | -377.99 | -375.771 |
| Adj. Pseudo $R^2$ | 0.266 | 0.266 | 0.271 |

(1) Standard error in parenthesis (2) ** Denotes significance at 5% level; *** Denotes significance at 1% level
Note: the pseudo-$R^2$ value in MNL functions is similar to $R^2$ in conventional analysis except that significance occurs at lower levels. Hensher and Johnson (1981) comment that values of pseudo-$R^2$ between 0.2 and 0.4 are considered extremely good fits.

## Results

A total of 207 completed questionnaires were used in the analysis. However, before turning to the discussion of the main results it should be noted that 52 respondents (25%) always selected the *status quo* option. Most of those, selecting this alternative, where protesting to pay for a program, which in their opinion should be financed by the government. These "protest answers" were omitted from the analysis; where only positive and genuine zero bids were included.

The results of three different models estimated by the regression analysis are given in Table 2. In all of them the signs of the estimated coefficients were as expected and most of the variables are statistically significant at the 99% confidence level.

The negative sign in the burnt area, tree mortality and payment variables indicate that in average the Catalan population considers that higher values of these attributes decrease their welfare; i.e. less burnt area and dead trees are preferred.

The different estimated models are further exploring the preferences for applying a certain type of fuel reduction methods. These preferences, along with any other systematic unobserved effects, are captured by the alternative specific constants (ASC) (Blamey et al. 2000).

In total three different models were estimated. In Model I the alternatives of applying prescribed burning (ASCPB) and physical fuel reduction (ASCPR) are compared to the *status quo* alternative. Both ASCs are statistically significant (i.e. different from zero) and positive. Meaning that both alternatives, where additional prevention measures are applied, are preferred to the alternative without additional prevention.

Model II intends to estimate whether the respondents have any preferences regarding the type of methods applied to conduct the additional forest fire prevention measures. Therefore the alternative of applying prescribed burning was compared with two other alternatives. Also in this model both ASC were statistically significant. The negative sign of the *status quo* constant (ASCSQ) confirms the result of Model I, that conducting additional prevention measures by prescribed burning is preferred to the option of no additional prevention. The positive value and statistical significance of the physical fuel removal alternative (ASCPR) is indicating that this alternative is preferred to the prescribed burning alternative.

**Table 3.** Marginal values.

| Attribute | Marginal value (€) |
|---|---|
| Burned forest area | -0.85 [-1.121,-0.63] |
| Dead trees | -0.79 [-1.041,-0.524] |

(1) 95% confidence intervals in brackets; (2) Marginal values are expressed in 2007 Euros

To further inquire what might be the reason for this preference Model III was estimated. It was based on Model II by adding the dummy variable indicating respondent's knowledge about prescribed burning (NOPB). This variable takes value 0 if the respondent, before conducting this questionnaire, was not familiar with the prescribed burning method and 1 if he was. There are no changes with regards to the *status quo* alternative, which remains less desired as the prescribed burning alternative. However, the alternative specific constant of the physical removals is no longer statistically significant. This means that this alternative is not preferred compared to the prescribed burning alternative. The explanation is given by the NOPB variable. This variable is statistically significant at 95% confidence level and positive. It expresses that individuals who were familiar with the prescribed burning method are more likely to select this alternative.

Table 3 reports the marginal values, along with their standard errors, for the burned area and tree mortality attributes. This marginal value can be inferred by calculating

$$p_a = {}^{-\beta_a}\!/_{\alpha} \tag{3}$$

, where $\beta_a$ is the regression coefficient of the attribute to be valued and α the coefficient of the attribute expressed in monetary units (i.e. price) (Louiviere et al. 2001). The confidence intervals for the marginal value for each attribute were calculated using the Krinski and Robb (1986) procedure with 2000 repetitions.

The values indicate that (i) for a decrease of burned forest area by 1 hectare per 1000 the individual, on average, would be willing to contribute 0.85 euros per year, and (ii) for a decrease in the average tree mortality caused by forest fires of one percentage point (e.g. from 30 to 29 dead trees per 100), on average, the respondents would be willing to pay 0.79 € per year.

These values might be used to estimate the value of applying different prevention scenarios. However, it should be noted that some limitations exist. The values were estimated using given levels for each attribute (Table 1). It is uncertain if using different levels, outside this range, would result in same estimated values, since respondent's perception might vary.

## Discussion

In this study it was intended to explore (i) what values people place on changes of burned forest area and decreased share of tree mortality caused by forest fires, and (ii) what are respondents' preferences related to applying different fuel reduction measures.

Regarding the first point the marginal value of the two attributes was estimated. For both we obtained negative marginal values. This was expected, since an increase in burned area or tree mortality was considered as having negative influence on the individual's utilities. The results are consistent with the answers obtained in the introduction to the questionnaire. There respondents were asked to select their preferred situation with regards to different levels of burned area and tree mortality. For both attributes approximately 94% of the respondents selected the lowest levels. Based on these results it may be concluded, that the implementation of an additional forest fire prevention program would increase the welfare of the Catalan population and that on average the population would be willing to pay for its implementation.

The second purpose of this study was to obtain information on the preferences the Catalans have regarding the application of different fire prevention methods, namely prescribed burning and physical fuel reduction. This question was of particular interest, since prescribed burning is still not widely accepted and applied in Spain (Xanthopolus et al. 2006). Furthermore, most awareness campaigns described any type of fire in the forest as bad. Therefore, the concern exists that using fire for fuel management might be rejected by the public.

However, the regression analysis results demonstrated that the public is indifferent which method is used to implement additional prevention. This is consistent with the responses to additional questions, where no differences were detected between the shares of respondents supporting the use of physical fuel reduction methods and prescribed burning. Also when explicitly asked to select which method the respondents prefer, 24% replied prescribed burning, 36% physical removal and 26% were indifferent.

However, the results also demonstrated that a part of the population is still not informed about the possibilities of applying fire as a management tool. Therefore it would be important to put more efforts on information and education campaigns, before widely applying prescribed burning.

One final remark should be placed on how the respondents perceived the scenario applied in this study. Fire prevention measures and the benefits of applying them might be less known among the general population. This might cause the respondents to over- or underestimate the effects of the application of such measures and express their support based on wrong assumptions. We tested this by asking the respondents what, in their opinion, is the possibility that a forest fire occurs after prevention measures have been applied. Only around 4% of the respondents answered that it is not possible at all, while the rest considered that even after the prevention measures have been applied forest fires may occur.

In summary, this study showed that the Catalan society considers the implementation of additional forest fire prevention as beneficial and would support it. It also showed that both of the proposed methods for the implementation of such program (i.e. prescribed burning and physical fuel removal) are considered as acceptable by the society. However, more efforts should be devoted to inform the population about the possibilities and benefits of applying new types of prevention methods, such as prescribed burning.

## Acknowledgments

This study was supported by the EU financed project FIRE PARADOX: An Innovative Approach of Integrated Wildland Fire Management Regulating the Wildfire Problem by the Wise Use of Fire: Solving the Fire Paradox (FP6-018505). We would also like to thank Dr. José Ramón Gonzalez for his suggestions, explanations and comments.

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# Fuzzy Multi-Criteria Modeling for Impact Assessment in the Context of Sustainable Forest Management: A Greek Case Study

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## Abstract

Most decisions in the context of sustainable multiple use forest management need to be derived after consideration of various impacts, including environmental, socio-economic and institutional. Moreover, very often some impact values are expressed in fuzzy terms. This paper presents a fuzzy multi-criteria approach based on spatially referenced indicator models to assess sustainability of forest management actions by considering different multiple impacts. The approach is tested in a Greek case study. Different impacts of a complex forest restoration project following a big forest fire in Kassandra of Halkidiki in Northern Greece were traded-off to measure the performance of the "project option" versus the "no project option" toward forest management sustainability. Implementation of the model suggested that the "project option" contributes more to forest management sustainability than the "no project option" and therefore the forest management Authorities should adopt it.

*Keywords: spatial impact indicator models; multiple use forest management*

## 1. Introduction

The most complicated decisions from the operational point of view managers of the Mediterranean forests have to make are associated with their efforts to evaluate *ex-ante*, *ex-post* or *on-going* projects and/ or activities in the context of sustainable multiple use forest management. This is mainly due to the fact that most of the existing evaluation tools can hardly measure the contribution of forestry projects and/ or activities to forest management sustainability, because they fail to incorporate all their different types of impacts, such as environmental, social and economic, as these are usually different at different spatial scales, time scales and levels of aggregation. In addition, most of the attributes related to environmental, social and economic forestry project impacts are vague, subjective, intangible or uncertain.

The best known and most commonly used analytic tool since the 1960s to address the welfare economics issues has been the Cost-Benefit Analysis. However, the application of Cost-Benefit Analysis for forestry project evaluation in the context of sustainable forest management poses several problems, which are difficult to overcome, such as the appropriate decision rule (Net Present Value, Internal Rate of Return, etc), the forest discount rate, the treatment of risk and the distribution issue (Gregersen 1992; Bonnieux et al. 2004). The need to also consider environmental issues in forestry project evaluation analysis since the late sixties has stimulated the search for other analytic tools. Several methods appeared to allow monetization of non-market values in order to include those in the Cost Benefit Analysis framework (Johansson 1993; Cornelis van Kooten 1995; Cesaro et al. 1998; Campos et al. 2007). However, several philosophical/ethical issues have arisen in many cases with this type of analysis. Multi-Criteria Analysis was presented then as the alternative to Cost-Benefit Analysis.

Multi Criteria Analysis was originated from the Operations Research field and includes several methods, which usually provide alternative solutions (trade-off information) in relation to many different, often conflicting, objectives under various types of constraints (Cohrane and Zeleny 1973; Keeney and Raiffa 1976; Zeleny 1981; Reza and Steiner 1988; Pukkala and Miina 1997; Borges and Hoganson 1999; Kurtilla et al. 2002; Kazana et al. 2003; Falcao and Borges 2005). Multi Criteria Analysis provides a more realistic framework for decision- making analysis than Cost-Benefit Analysis. However, at the operational level forestry project evaluation in the context of sustainable forest management requires balancing against each other and integrating the many usually vague, subjective, intangible, little known and uncertain factors associated to sustainability, so as to measure the relative contribution of the project under concern to forest management sustainability. Fuzzy logic can be used in this respect to form useful operational decision making tools, as fuzzy models are word based, nonlinear changeable and analog (ambiguous), not digital (yes/no). In other words, fuzzy logic provides answers of "maybe" type and values range anywhere from 0 (NO) to 1 (YES), while crisp sets can handle only 0s and 1s and the answer is either "YES" or "NO". Fuzzy Sets handle all values between 0 and 1 and the answer can be "no", "slightly", "somewhat", "sort of", "a few", "mostly", "yes", "absolutely" (Bellman and Zadeh 1971; Dubois and Prade 1988; Smith 1994; Cornelissen et al. 2000; Phillis and Andriantiachaholiniaina 2001; Kazana et al. 2005; Mendoza and Martins, 2006). A model of this type has been developed through MEDMONT, an EU funded research project to assess project sustainability in mountain Mediterranean areas.

## 2. The MEDMONT multi-criteria fuzzy model for forestry projects sustainability assessment

The MEDMONT multi-criteria fuzzy model is part of the MEDMONT integrated evaluation framework for project sustainability assessments in the mountain Mediterranean areas (Kazana et al. 2005).

MEDMONT relates target groups with the project evaluation and monitoring processes and tools by integrating three dimensions: spatial scale, level of aggregation (or level of detail) and method of approach (top-down and bottom up). It involves: i) a natural resource base and capability evaluation, ii) a socio-economic evaluation, iii) an institutional evaluation,

iv) a green accounting evaluation, v) a social preference evaluation and vi) an integrated evaluation based on Multiple Criteria Analysis and Fuzzy Logic.

With regard to spatial scale MEDMONT is based on the concept of spatial entities, that is, spatial units meaningful for development analyses. These entities are formed to reflect the dynamic relationship that exists between the spatial patterns of natural resources and the socioeconomic spatial activity patterns at any certain geographic location. Spatial entities generally exhibit homogenous human impact history and present similar development opportunities and/or restrictions and also respond in similar ways to development changes. A four-level hierarchical spatial system is used involving the landscape region, the landscape system, the landscape type and the ecotope. The landscape system typology involves minimum mapping units of 1–5 $km^2$ and a pattern of ecosystems described with physiographic attributes. The landscape type typology uses as the major defining parameter the land use/ cover and minimum mapping units of 200 $m^2$, while ecotopes are recognizable subunits of ecosystem types with minimum mapping units of some $m^2$. The level of aggregation (or level of detail) is expressed in the form of a hierarchy of processes and a measure of aggregation of processes. Generic landscape systems and types were identified for the entire European Mediterranean mountain region and used to construct Natural Resource Evaluation Models (NREM) for forestry, agriculture, grazing, recreation, water/soil and wildlife corresponding to high level of aggregation. The suitability/ impact values of the NREM models may range from 1 to 20 with 20 representing the highest possible suitability/ impact value. The model values represent the relative suitability/ impact of any spatial entity characterized by a particular landscape system/ landscape type combination to sustain a relative level of any selected indicators for a particular resource. These values also represent the importance of possible negative or positive impacts of any resource/ indicator/ spatial entity. For illustration purposes, Tables 1 and 4 show the NREM suitability/ impact indicator models for forestlands (Kazaklis and Kazana, 2004). Similarly socio-economic, green accounting and institutional impact indicators were spatially referenced for the landscape system and landscape type spatial scales, called Human Resource Impact Evaluation Models (HRIEM).

The MEDMONT fuzzy multi-criteria evaluation model provides forestry project sustainability impact assessments by considering the dynamics of two subsystems, the natural resource impact changes and the human impact changes (Figure 1).

The overall project sustainability is then, in this respect, a nonlinear function of the individual constituents' sustainability and it is constructed logically by using fuzzy logic. Specialist experts using the MEDMONT spatially referenced impact indicator models evaluate each subsystem. Natural resource impact changes are estimated with the NREM and the human impact changes are estimated with the HRIEM in the form of a composite indicator, the Estimated Impact Units (EIUs). EIUs are calculated for each alternative including the "no project option" by multiplying the corresponding indicator rating by the land parcel area affected by the alternative under evaluation (Kazaklis and Kazana 2004). Indicator impact units are assessed as % loss or % gain from a baseline condition, which is always the "no project option" (Kazana et al. 2005). The combination of the impact loss and impact gain by means of fuzzy logic provides a measurement of sustainability for each subsystem. Therefore, in the model's general form, 8 secondary linguistic variables ($AGR_{imp}$, $FOR_{imp}$, $RANGE_{imp}$, $WATER_{imp}$, $REC_{imp}$, $WLIFE_{imp}$, $SECON_{imp}$, $INST_{imp}$) are considered to obtain the two primary linguistic variables, the natural resource impact change ($NRES_{imp}$) and the human resource impact change ($HRES_{imp}$).

To assess a forestry project sustainability three primary linguistic variables are used, $NRES_{imp}$, $HRES_{imp}$ and the Project Sustainability Impact Assessment, PSIA. The primary linguistic variables take the linguistic values Very Low (=VL); Low (=L); Moderate (=M); High (=H); and Very High (=VH).

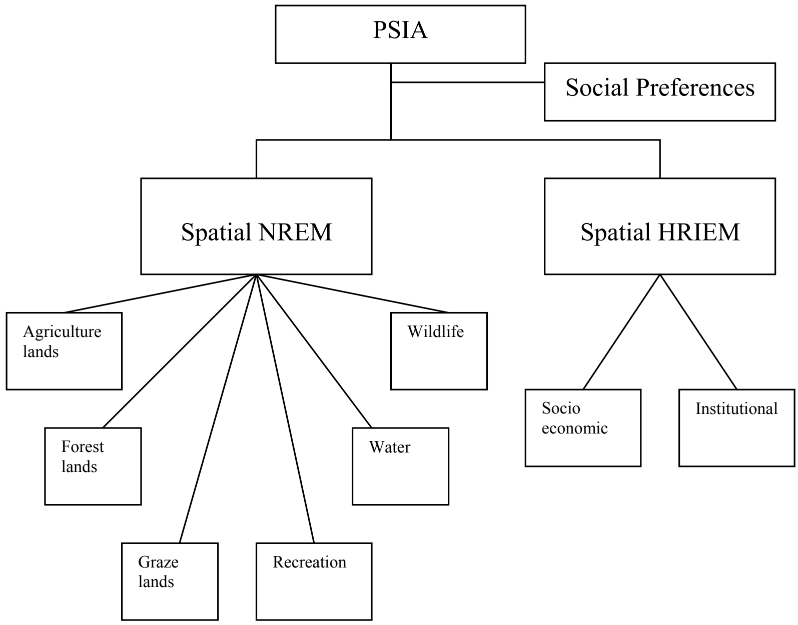


**Figure 1.** Constituents of forestry project sustainability in Mediterranean forest areas.

The linguistic values for the secondary linguistic variables are Non Significant (=NS), Little Significant (=LS), Moderately Significant (=MS); Significant (= S); and Very Significant (=VS). Each secondary variable is the fuzzy combined result of two variables denoting impact Loss or impact Gain from the baseline condition (no project option). For example, $FOR_{imp}$ is the result of $FOR_{imp}$_L and $FOR_{imp}$_G, which take on similar to $FOR_{imp}$ linguistic values.

Triangular membership functions are used for the secondary variables and trapezoidal functions are used for the primary variables to represent the increased uncertainty involved in the computation.

To fuzzify the Estimated Impact Unit (EIU) value, in the Gain case, the land parcel area affected by the project multiplies the maximum possible value, which could be obtained. By applying the following formula the max EIUs are estimated, which correspond to the value of 1. The EIU value is then fuzzified by deduction. In the Loss case, the min value, that is, 0 is taken.

$$\frac{(\text{EIUs-max for alternative Pi}) - (\text{EIUs for baseline condition})}{(\text{EIUs for baseline condition})} \times 100$$

The value of each primary linguistic variable is given by the average aggregation of the estimated values of the secondary linguistic variables.

Simulation of the evolution of the system is represented by rules of the form of “IF (antecedents) – THEN (consequent)”, where the implication operator “THEN” and the connectives “AND” among antecedents are fuzzy. The rules are expressions of the role of interdependencies among different kinds of project impact changes. To determine PSIA, the contribution of the forestry project to sustainable forest management, the rule base needs 52= $2^5$ rules, because there are 5 linguistic values and 2 variables. Different linguistic rule bases can be built according to knowledge acquisition (social preferences).

To express quantitatively the fuzzy rules the "AND", "OR", or "IF-THEN" connectives may be used. The connective "OR" is expressed by the max-max operator, while the "AND" connective by the γ-operator defined as γ-operator = γ-minimum + (1-γ) maximum, where $\gamma \in [0.1]$. If γ=0.5, equal weight on the maximal and minimal values is assigned. Smaller values of γ emphasize the maximum and larger values emphasize the minimum. Finally, defuzzification, which is the final operation to convert membership grades into a single crisp value, is done with the center-of gravity formula, as it complies with the averaging process used before fuzzification of the input. So, the crisp value for project contribution to sustainable development is given by

$$Def(T_{PSIA}) = \frac{\sum_j y_i \cdot \mu_{T_{PSIA}}(y_j)}{\sum_j \mu_{T_{PSIA}}(y_j)}$$

Where, $y_j$ is the value of the jth element of the fuzzy set $T_{PSIA}$, and $\mu_{T(PSIA)}$ $(y_j)$ is the membership grade of the $j^{th}$ element of the fuzzy set $T_{PSIA}$.

The fuzzy MEDMONT model runs with the MATLAB fuzzy toolbox.

## 3. A Greek forestry project case study

The MEDMONT fuzzy multi-criteria project sustainability impact assessment model is demonstrated in a real forest restoration project in the province of Halkidiki, Greece (Figure 2).

The project concerns the restoration of the Agia Paraskevi – Pefkohori burnt pine forest area, extended over 1735 ha in the Pallini Municipality of Kassandra, Halkidiki in Northern Greece. The main objectives of the restoration Agia Paraskevi-Pefkohori burnt area project are to prevent soil erosion and flood damages to the nearby residential areas, to reduce the forest fire risk and to quickly restore the burnt forest area.

In order to achieve the objectives the project involves the following tasks:

- Removal of the burnt and damaged wood
- Construction of brush dams and bole dams in the burnt areas of high fire risk for soil erosion protection from the dead trees found on site or transported from neighbouring sites (life duration 5 years)
- Construction of small wooden dams for flood protection (life duration 5 years)
- Construction of small concrete dams (life duration 20 years)
- Natural regeneration of the pine burnt forests of the area. This process involves silvicultural regimes, such as wide sowing using seeds all over the surface (1 kg seed/ 0.1 ha) or sowing in rectangles (0.3 m × 0.5 m × 0.15 m) with the largest side along the isoclines and supplementary planting with seedlings.

This type of project is quite typical in high fire risk Mediterranean forest areas, such as Halkidiki. The total cost of the project amounted to 1 014 675 Euros and it was covered fully by public funding.

The project sustainability impact is assessed in comparison to the no-project alternative (baseline condition).


**Figure 2.** Location map of the Kassandra-Halkidiki study area, northern Greece.

Tables 1, 2 and 3 show the selected forestlands and rangelands, as well as the socioeconomic impacted indicators by the forest restoration project. Selection was made using the MEDMONT NREM and HRIEM models at the landscape spatial scale. For demonstration purposes in this paper only the forest lands and the rangelands impacts were estimated to record the natural resource impact change and only the socio-economic impacts to record the human resource impact change.

Once the values of the secondary linguistic variables $FOR_{imp}$, $RANGE_{imp}$ and $SECON_{imp}$ are estimated for the Restoration of the Agia Paraskevi-Pefkohori burnt forest area project, the MEDMONT multi-criteria fuzzy model is run with the MATLAB fuzzy toolbox and the degree of the project contribution to sustainable multiple use forest management of the area on a scale from 0 to 100 is computed. Figure 3 presents the final output value (PSIA value) for the two alternatives, that is, project/ no project of the project under concern.

A linguistic rule base, where the maximal value of one variable dominates all others was used to estimate the final output (PSIA value). On the basis of social preferences, more weight was put on the natural resource impact changes over the human resource impact changes.

The final PSIA value implies that the project option after balancing the natural resource and the human resource impacts is more preferable in forest management sustainability terms. In other words, a rational forest manager should select the project option, since this contributes more to forest management sustainability of the area than the no project option.

The MEDMONT fuzzy multi-criteria model is an easy to use tool from the operational point of view for assessing project impacts in the context of sustainable multiple use forest management. In addition, as the project sustainability constituents are based on the natural resource, socio-economic and institutional evaluation base of the MEDMONT framework makes it consistent with sustainable mountain development.

**Table 1.** Forest lands impacted indicators- Forest Restoration Project Agia Paraskevi- Pefkohori, Halkdiki, Greece.

| Forest lands impacted indicators |
|---|
| 1. Conservation of soil/moisture |
| 2. Conservation of landscape aesthetic value |
| 3. Conservation of water quality |
| 4. Preservation of air quality |
| 5. Prevention of soil erosion |
| 6. Prevention of catastrophic floods |
| 7. Prevention of wildfires |
| 8. Prevention of landslides and avalanches |
| 9. Wood production |
| 10. Production of nut and other food types (for human and wild fauna consumption) |
| 11. Production of seeds |

**Table 2.** Rangelands impacted indicators- Forest Restoration Project Agia Paraskevi- Pefkohori, Halkdiki, Greece.

| Rangelands impacted indicators |
|---|
| 1. Herbage production |
| 2. Browse production |
| 3. Livestock related production |
| 4. Conservation of soil/moisture |
| 5. Conservation of flora biodiversity |
| 6. Conservation of landscape values |
| 7. Improvement of soil fertility |
| 8. Improvement of rangeland production (quality/ quantity) |

**Table 3.** Socioeconomic impacted indicators –Forest Restoration Project Agia Paraskevi-Pefkohori, Halkidiki, Greece.

| Socioeconomic impacted indicators |
|---|
| 1. Intermediate consumption / ha |
| 2. Ordinary output/ ha |
| 3. Quality of products/ ha |
| 4. Outdoor activities/ ha |

The MEDMONT fuzzy multi-criteria model can also be uniformly applied to all levels of decision making and to a wide variety of project categories. Finally, social preferences are incorporated in the evaluation process to balance the impact changes between the natural and the human resources, expressed through the linguistic rule base of the model.

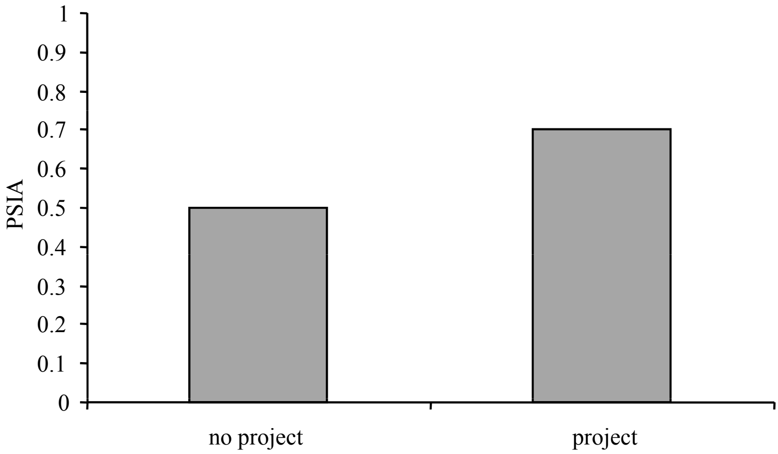


**Figure 3.** Project impact assessment in terms of multiple use forest management sustainability- Forest Restoration Project Agia Paraskevi- Pefkohori, Halkdiki, Greece

## 4. Conclusions

The MEDMONT fuzzy multi-criteria model is a tool which can be used to balance and integrate environmental, social and economic project impacts in the context of sustainable multiple use forest management. The model structure is based on fuzzy logic and therefore the model can successfully deal with attributes related to project impacts that are vague, subjective, intangible or uncertain.

The constituents of the project sustainability draw upon the Natural Resource Evaluation Models (NREM) and the Human Resource Impact Evaluation Models (HRIEM) of the MEDMONT integrated evaluation framework. As a result of this the model is consistent with mountain sustainable development, is applicable to a variety of project categories and it can be uniformly applied to all levels of decision- making. The model also incorporates social preferences in the evaluation process to balance natural resource and human resource impacts, expressed through its linguistic rule base.

## Acknowledgements

The present paper is part of "Tools for evaluating investment in the Mediterranean mountain areas. An integrated framework for sustainable development – MEDMONT" (QLK5 – CT-2000-01031), undertaken in collaboration with the MAI.Ch - CIHEAM (Dr. Vassiliki Kazana (coordinator) and Mr. Angelos Kazaklis, University of Padova (Prof. Maurizio Merlo, Dr. Paola Gatto and Dr. L. Croitorou), INRA (Dr. Francois Bonnieux and Dr. Jean-Cristophe Paoli), CSIC (Dr. Pablo Campos Palacin) and University of Ljubljana (Prof. Lidija Zadnik).

The paper is also part of " Project Evaluation for Sustainable Development and Management of Mountain Areas – A Decision Support System" undertaken at the Technological Education Institute of Kavala, Greece ("EPEAEK, ARCHIMEDES I, Dr. Vassiliki Kazana (co-ordinator), Mr. Angelos Kazaklis, Prof. Ioannis Takos, Dr. Theodora Merou, Prof. Nikos Eleftheriadis, Prof. Vassilis Papanastasis).

**Table 4.** Generic Mediterranean Forest resource suitability/ impact evaluation model (MEDMONT NREM)

| Landscape systems | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alluvia 0-300m | 12 | 12 | 16 | 15 | 17 | 15 | 14 | 16 | 13 | 16 | 17 |
| Alluvia 300-800m | 17 | 18 | 14 | 15 | 13 | 15 | 14 | 14 | 17 | 14 | 13 |
| Alluvia 800-1800m | 14 | 13 | 15 | 17 | 14 | 14 | 12 | 16 | 12 | 14 | 14 |
| Alluvia >1800m | 11 | 18 | 15 | 11 | 18 | 15 | 14 | 17 | 13 | 13 | 18 |
| Soft Sedimentary Rocks 0–300m | 15 | 13 | 15 | 14 | 16 | 13 | 16 | 13 | 12 | 15 | 16 |
| Soft Sedimentary Rocks 300–800m | 19 | 13 | 16 | 15 | 15 | 18 | 12 | 15 | 15 | 13 | 15 |
| Soft Sedimentary Rocks 800–1800m | 17 | 16 | 14 | 16 | 14 | 13 | 15 | 15 | 16 | 10 | 14 |
| Soft Sedimentary Rocks >1800m | 16 | 16 | 14 | 15 | 17 | 11 | 18 | 17 | 13 | 16 | 17 |
| Hard Sedimentary Rocks 0–300m | 14 | 14 | 12 | 17 | 15 | 15 | 14 | 17 | 16 | 12 | 15 |
| Hard Sedimentary Rocks 300–800m | 17 | 18 | 14 | 14 | 15 | 14 | 14 | 14 | 15 | 14 | 15 |
| Hard Sedimentary Rocks 800–1800m | 15 | 16 | 17 | 17 | 12 | 14 | 10 | 14 | 15 | 13 | 12 |
| Hard Sedimentary Rocks >1800m | 10 | 14 | 13 | 11 | 13 | 13 | 14 | 18 | 13 | 16 | 13 |
| Igneous Rocks 0–300m | 13 | 16 | 14 | 12 | 15 | 17 | 14 | 17 | 13 | 14 | 15 |
| Igneous Rocks 300–800m | 15 | 14 | 16 | 17 | 13 | 11 | 15 | 14 | 14 | 16 | 13 |
| Igneous Rocks 800–1800m | 14 | 19 | 17 | 14 | 17 | 15 | 15 | 16 | 14 | 13 | 17 |
| Igneous Rocks >1800m | 12 | 16 | 15 | 12 | 15 | 13 | 14 | 19 | 16 | 16 | 15 |
| Foliated Metamorphic Rocks 0–300m | 16 | 13 | 10 | 12 | 12 | 16 | 12 | 17 | 12 | 13 | 12 |
| Foliated Metamorphic Rocks 300–800m | 11 | 15 | 13 | 18 | 13 | 13 | 12 | 14 | 15 | 16 | 13 |
| Foliated Metamorphic Rocks 800–1800m | 14 | 18 | 14 | 15 | 16 | 13 | 12 | 14 | 12 | 11 | 16 |
| Foliated Metamorphic Rocks >1800m | 14 | 15 | 11 | 15 | 14 | 12 | 11 | 18 | 16 | 16 | 14 |

* Values correspond to the 11 forest land impacted indicators reported in Table 1

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# Production Potentiality in Fruits, Biomass, Oil, Essential Oil and Medicinal Properties of the Mastic Tree (*Pistacia lentiscus*) in Kroumirie, N-W Tunisia

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## Abstract

The mastic tree (*Pistacia lentiscus*) is a natural species from the anacardiaceous family. In the Mediterranean area, it's a well-known shrub, which generally grows with *Erica arborea*, *Arbutus unedo*, *Cistus salviifolius*, *Phillyrea latifolia* and *Myrtus communis*.

In Tunisia, the mastic tree grows spontaneously in the North West of Tunisia and Cap Bon but we can find it in some other localities such as Séliana, Krib, Teboursouk, Testour and at the gate of the desert: Matmata, Bouhedma.

To give an idea about the potentialities (cover, bio volume, bio mass) of this species, some studies have been realised. They have shown a cover of 600 m²/ha, a bio volume of 1000 $m^3$/ha, a production of dry material 800 Kg/ha and an average fruit production of 1 to 1.5 tonnes/ha. This species is wanted for its fruits, its resin and its essential oil extracted from the leaves. The fruit has an edible kernel. From this fruit we can extract a fixed oil. Its yield varies from 8 to 18%. Yields of essential oil are affected by two factors: Drying and cutting. A survey realised with the population of the North West of Tunisia has specified the different medicinal properties of this species.

*Keywords: mastic tree; production; distillation; medicinal properties.*

## 1. Introduction

The understorey of the Tunisian North West forests is very varied. It is essentially composed of *Pistacia lentiscus*, *Myrtus communis*, *Erica arborea*, etc. In general, each of these species is used for a very specific end: Mastic tree for its essential oil and extracted oil from its fruits, the myrtle for its essential oil, and the heather for manufacturing pipes.

EFI Proceedings No. 57, 2009
Modelling, Valuing and Managing Mediterranean Forest Ecosystems for Non-Timber Goods and Services
Marc Palahí, Yves Birot, Felipe Bravo and Elena Gorriz (eds.)

To valorise this very varied understorey, we were interested in the production potentiality of fruits, biomass, biovolume, cover, essential oil and the different medicinal utilizations of the mastic tree. The essential oil is extracted from leaves. The extraction process used is extraction by steam. The vegetal or fixed oil is extracted in a traditional way after crushing and purification.

## 2. Material and methods

### 2.1 Plant material

#### 2.1.1 Presentation of the mastic tree

The mastic tree belongs to the *Anacardiacea* family, which contains about 600 species and more than 70 kinds. Its natural range is discontinuous and has four phytogeographical regions: the Mediterranean, Irano - touranienne, Sino-Japanese and Mexican regions.

Around the Mediterranean Sea, there are about 6 species. In the West it can be limited to the Canary Islands and in the North, to Portugal, Spain, France, Italy and Greece. In North Africa, it ends in the zones where we can find *Juniperus oxycedrus*. It is rare in Tripoli; but it becomes abundant in Cyrenaïc region. In Tunisia, the mastic tree grows spontaneously in the North of Tunisia and the Cap Bon; but we find it in some other regions like Séliana, Krib, Teboursouk, Testour; and at the gate of the desert: Matmata, Bouhedma. The species is represented by trees or shrubs, but rarely as a climbing plant and never as an herbaceous plant. The bark, wood and other parts are especially developed. They produce some substantial resins. We meet *Pistacia lentiscus* and *Pistacia terebenthus* in Tunisia.

The Anacardiaceas family is classified as:

- Embranchement: Spermaphytes;
- Under embranchement: Angiosperme;
- Class: Magnolipsides (dicotylédones);
- Order: Apetalous
- Family: Anacardiacea;
- Genre: *Pistacia*;
- species: *lentiscus*;
- Vernaculaire Name: Arabic Name: therou. (ورذ)
  French Name: lentisque; arbre à mastic.

#### 2.1.2 Botanical characteristics

It is a vivacious shrub, often in the state of a small shrub that can exceptionally reach a height of 7 to 8 meters; garnished with narrow small leaves that spread a pleasant perfume. Leaves are evergreen.

Bark: The bark is resinous and has a reddish or grey colour

Wood: The wood of the mastic tree is hard. It is not used for construction, but it gives an excellent charcoal.

Leaves: Leaves are paripinnate, 3 to 12 leaflets, with dark green colour, shiny at the upper part, are 2 to 4 cm long and 7 to 15 mm in size. The total length of the leaf can be 6 to 10 cm and a total width of 3 to 7 cm.

Fruits: The spherical fruits are first green, then red and black at maturity; often used for the extraction of oil and contain some small edible almonds. The berry of these fruits is used for the manufacture of perfumes. This fruit is also very appreciated by livestock (particularly goats and sheep).

Inflorescence: Flowering begins at the end of January, beginning of February and lasts for about one month (exceptionally certain trees can bloom very late: end of April and beginning of May). The male trees carry small reddish flowers in which we can find 3 to 5 stamens whose anthers are voluminous. The female trees have flowers composed of round ovaries, surmounted by short styles with three stigmas.

#### 2.1.3 Geographical distribution and ecological requirements

It is a Mediterranean species, well-known in the northern part of Tunisia: Kroumirie, Mogods, Zaghouan, Siliana, the region of Kesra, Le Cap Bon and even in the south of the country, in southern exposure (Matmata and Bouhedma).

It is a semiarid to sub-humid level species; with hot to moderate variants. We find it in the humid, under low level in its soft winter variant from 600 mm/year. It remained frequent in the entire upper semiarid. By small localities, it is present up to less than 300 mm/year. In arid regions with desert climate, it remains rare except in the case where there are certain compensating factors (temporarily humid lump, clayey substratum or clayey Limon). It is generally indifferent to soil, but likes the heavy, calcareous clay and clayey soils. In Kroumirie, it is abundant in humid cork-oak forests up to an altitude of 600 m. Over this altitude, it is stressed by the cold weather and snow but it bears cold weather and humidity better than wild olive trees (*Olea europeae*).

### 2.2 Methods

#### 2.2.1 Survey for mastic tree fruit production potentialities

This survey has been conducted in the Kroumirie – Mogods cork oak forest; especially in Tabarka, Ain Drahem, Bellif and Tebabba forests. Eight stationary plots of 5000 $m^2$ have been selected and distributed on different regions of Kroumirie. In every plot, the following measurements have been taken: the clump diameter, its height and its fruits location.

Fruits productions: Sex of the clump is determined and fruits are picked and weighted. Colour of the fruits determine the maturity stage: black (mature), red (premature) and green (non mature).

The site of every clump has been listed to follow the production according to years. The evaluation of the production in fruits has been made during four successive years.

#### 2.2.2 Survey of cover, biovolume and dry biomass

To value the cover, the biovolume and the dry biomass of every understory (*Pistacia lentiscus*, *Myrtus communis*, *Erica arborea*, *Erica scoparia*, *Phillyrea latifolia*) 40 plots of 16 $m^2$, were randomly distributed on a map with a scale of 1/50 000 and then in the field (Saidi et al 2006).

In every plot, the following measurements were taken: the diameter of the clump, its height and its sex.

For every mentioned species, at least forty different bio volume clumps have been cut and weighted to estimate their distilled dry biomass (Luis-Calabuig 1987). A sample of 2 kilograms for every species have been cut then dried in an oven for 72 hours at a temperature of 100°.

The relation between the biovolume and dry biomass is established by regression for every species.

To determine the distillable dry biomass, we weighted the distillable part which contains leaves and the woody part. It was dried in an oven at 100° for 72 hours to help establish the relation between the biovolume, dry biomass and the distillable one.

### 2.2.3 Survey of essential oils

The essential oils are fragrant volatile substances in plants. They can be located in leaves as well as in barks. Four types of distillation tests have been performed during the spring period and conducted in this way:

- First test: fresh material.
- Second test: pounded fresh material.
- Third test: crunched material after 4 days from the date of the picking.
- Fourth test crunched material after 6 days from the date of the picking.

The protocol repetition of this experiment is four times. The principal aim of this protocol is to test the effect of the cutting and the turning into the essential oil yield.

After every distillation, we measured the EOV. The output in essential oils is expressed in litre/ton. It represents the quantity extracted from the anhydrous weight after turning of pounded material. Mastic tree essential oils are less dense than water and can be separated by decantation after cooling the distillate.

The separation of the essential oil from the distillate (floral water), is made by a separator, then by a decantation ampoule. The measure of the collected quantity is done by means of a test-tube. The pure essential oil is kept in a coloured well-closed small glass bottle. A steam distiller with a capacity of 200 litters is used.

Humidity ratio = [(total biomass – dry biomass)/total biomass] × 100. PH is calculated by a pH paper. Density = (weight of 10 ml) / (volume = 10 ml).

### 2.2.4 Survey on mastic tree's medicinal qualities

An investigation has been conducted in the entire North West of Tunisia, relating to the yield of oil, the use of the mastic tree in all its shapes, concerning all ages and social classes. People were surveyed in one hundred households by delegation. It essentially covered regions of Sédjnane, Nefza, Tabarka, Aïn Draham, Fernana and Gahrdimaou. The investigation took 4 years (2002–2006).

### 2.2.5 Harvesting of the resin

The resin is normally secreted by the plant. The bark of the trunk slightly incised secretes a resin which has a pleasant smell. This incision enables its escape; but it is possible to harvest it in autumn when it's presented as whitish small balls.

**Table 1.** Mastic tree production potentialities compared to some other shrub species.

| Variable<br>Species | cover<br>in m²/ha | biovolume<br>in m³/ha | dry biomass<br>in kg/ha |
|---|---|---|---|
| *Erica arborea* | 1734 | 2757 | 2269 |
| *Phillyrea latifolia* | 1395 | 2123 | 1844 |
| *Myrtus communis* | 1000 | 1340 | 931 |
| *Erica scoparia* | 653 | 1087 | 1032 |
| *Pistacia lentiscus* | 600 | 1000 | 800 |

### 2.2.6 Oil analysis

Oil analysis has been made by the laboratory of Tunisian Oil Office. 12 samples have been selected from different areas of the Kroumirie and were analysed to get the maximum yield of oil and chemical composition.

## 3. Results

### 3.1 Mastic tree production potentialities

The measured parameters in the field (clump Diameter, Height, Weight) permitted us to calculate the cover in $m^2$/ha, the biovolume in $m^3$/ha and the dry biomass in Kg/ha. A regression of the shape $Y = a + b X + c X^2$ has been established between the diameter of clumps and the cover, between the diameter of clumps and the biovolume and between the biovolume and the dry weight for the four species. These selected species are chosen according to their degree of importance in association with the mastic tree. These results are summed up in Table 1.

Table 1 shows the importance of the mastic tree in the understory of the cork-oak forest. It is represented by a cover of 600 $m^2$/ha with a dry biomass of 800 Kg/ha. This recovery constitutes 10 to 40% of the cork oak forest under stand, forming 600 to 900 clumps by ha. 10 to 20% of these clumps are male trees.

### 3.2 Distillable biomass

The objective of this study is to find a relation between the biovolume, the total dried biomass, and the distillable dried biomass.

Tables 2 and 3 show that the female mastic tree has less total dry and distillable material than the male one. It appears that the development of the fruits does influence the general growth of the plant and consequently its biomass.

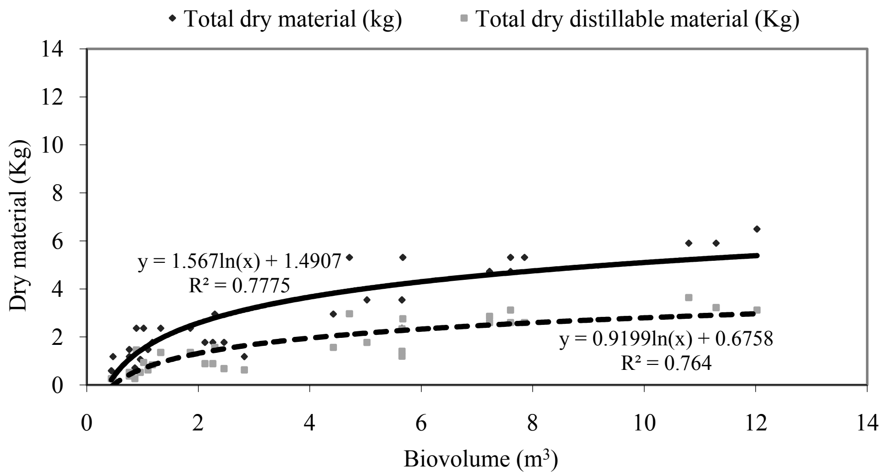


**Figure 1.** Relation between the Biovolume (m³), the total dried material and the distillable dried material for the female mastic tree.

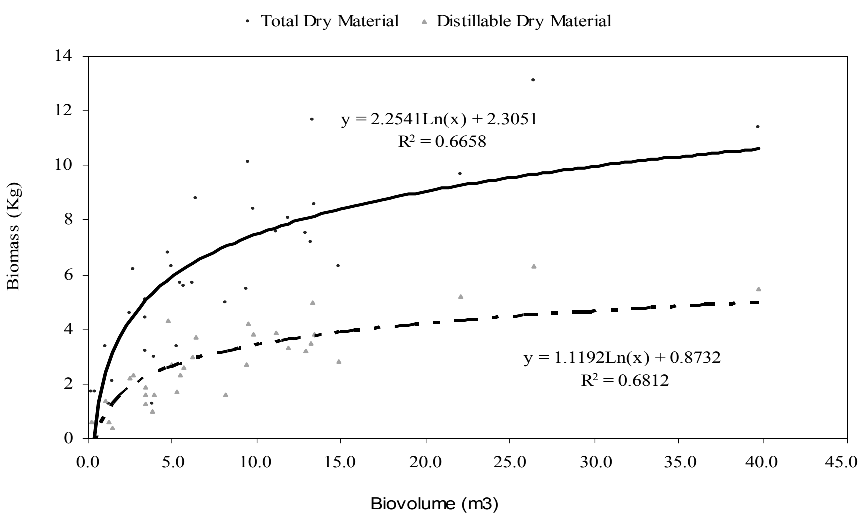


**Figure 2.** Relation between the Biovolume (m³), the total dried material and the distillable dried material for the male mastic tree.

### 3.3 Distillation results

Considering to the difference in biomass of the male and female clump, we have conducted the two types of distillation separately.

The first two types have been carried out to demonstrate the effect of the cutting and the two others the effect of the turning. These four test types have been repeated four times

**Table 2.** The average values of essential oil, in litre / ton (EOV) and the humidity ratio in percentage for the distilled female mastic tree.

| Distillation number | Humidity ratio % | EOV |
|---|---|---|
| Non crunched fresh material | 60 | 1.2 |
| Crunched fresh material. | 60 | 1.25 |
| crunched material after 4 days from the date of the picking | 29 | 1.2 |
| crunched material after 6 days from the date of the picking | 22 | 1.1 |

**Table 3.** The average values of essential oil, in litre/ ton (EOV) and the humidity ratio in percentage for the distilled male mastic tree.

| Distillation number | Humidity ratio % | EOV |
|---|---|---|
| Non crunched fresh material | 54 | 1 |
| Crunched fresh material. | 54 | 0.75 |
| crunched material after 4 days from the date of the picking | 45 | 0.4 |
| crunched material after 6 days from the date of the picking | 27 | 0.9 |

for each species and have given the results presented in Tables 4 and 5. These tables show that the quantity of essential oil decreases lightly after cutting the distillable material (fresh shoots) for the male mastic tree, but it is stable for the female tree.

The essential oil yield for the male mastic tree clump decreases clearly in the beginning of the drying and then increases and becomes higher than the fresh one.

The essential oil yield for the female mastic tree clump remains stable in all the tests.

The essential oil yield for the female mastic tree clump is more important than the male one and is not affected by cuttings or turning, but these two operations significantly influence the essential oil yield of the male mastic tree.

Physical analysis (pH and density) of the two types of essential oil has showed that the pH of the essential oil coming from the male trees varies from 3.5 to 4.5 and its density varies from 0.83 to 0.85. For essential oil coming from the female trees the pH varies from 3 to 4 with a density of 0.9.

### 3.4 Fruits and vegetal oil production

After pollination, the female mastic tree clump grows the fruits, which become blackish when they are ripe. A polynomial regression of the shape «$Y = a + bx + cX^2$» is established between the biovolume and the fruit production and has given the following results:

The average production in mastic tree fruits per ha is estimated at 1 to 1.5 tons in a good year and less then 0.1 ton in a bad year. They can get a copious production every 2 or 3 years. This production represents an important potential that can be valorised by the local industry.

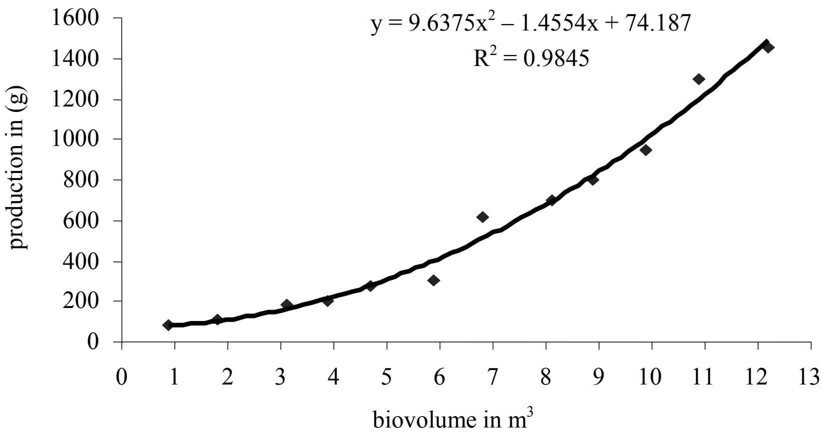


**Figure 3.** Fruit production Variation according to the Biovolume.

Fruits are hold on the two-year old wood and not on new shoots on a length of 3 to 6 cm. 90% of the fruits have a high density. 50 % have black colour (ripe fruits), 20% red colour and 30% yellowish green colour. The colour is the same for low density fruits.

Mastic tree fruits begin to ripe in September and October and finish in December and January. Harvesting is made in the ripeness period, generally by women, who select only the ripe fruits.

The extraction of the fixed oil is made in several stages. This work is generally done by women.

1. Fruit Gathering: They shake branches that carry fruits into kitchen utensils. Recovered fruits are placed in bags before transportation.
2. Cleaning: once in the processing location they are cleaned of all impurities (leaves, twigs…). After being sieved, they are placed in a water tank. Low density fruits float to the surface. They are generally green or red and are eliminated. Artisans say that they contain a very little amount of oil.
3. Crushing: once cleaned, they are crushed with a big sandstone roller. The resulting dough is put in high capacity tanks (more than 100 litres) then trampled down with feet. Twenty four hours later, we add cold water and then they are placed outside. The temperature is generally low enough to permit the solidification of oil with a part of oilcake. This solidified mixture is recovered and will be purified by several artisan methods that permit the separation of the oil from the remainder.

Oil yield varies from 8 to 18% according to the soil and the exposure (Ben Chikh 1999; Saidi 2003).

### 3.5 Oil analysis

Some samples of mastic tree oil have been analysed. Oleic acid is the more important component (50%), then palmitic acid (27.2%) and linoleic acid (19.3%). These substances valorise mastic tree oil.

**Table 4.** Results Analysis of mastic tree oil (Laboratory of Tunisian Oil Office):

| Fatty acid | Mastic tree oil |
|---|---|
| Oleic C18 ' | 50 % |
| Palmitic C16 | 27.2 % |
| Linoleic C18 ' ' | 19.3 % |
| Palmitoleic C16 ' | 1.7 % |

## 3.6 Mastic tree uses

### 3.6.1 Investigation results

The conducted investigation, compared to literature (Abdel Malek 2002; Ben Chikh 1999; Rjaibi 1996), has given the following conclusions:

- External Uses: treatment of burns and injuries (F.O), treatment of the chronic rheumatism (E.O), treatment of the gingivitis (L.P); the bark in fumigation against deliverance; resins in fumigation against fever. Irritation of the baby skin (F.O). Skin disease (L).
- Internal Uses: digestive tube treatment (L), bad breath treatment (R), against dry cough (F.O), stomach and abdomen pains (F.O), diarrhoeas (L), ulcers (L). Gastro-intestinal illnesses (root bark macerated in water), drying up of lips (F.O), cold and heavy cold; drops in nostrils (F.O); resins are chewed against throat pain, stomach pain and gastric trouble.
- Veterinary Uses: worms treatments (L). Liquid soap was used against ovine parasites.
- Other Uses:
  Manufacturing of Liquid Soap: ash leaves served to prepare a black liquid soap. It is also used to wash wool.
  Skin Tanning: Mastic tree leaves contain 12 to 14% of tannin and are therefore used in the tanning of skins.
  Organic Manure: leaves are very rich in potash and this gives them an exceptional fertiliser values.
  Charcoal: Mastic tree wood gives an excellent charcoal.
  Varnish: the resin can be used to make an excellent varnish.
  Chewing Gum: the resin is used as a chewing gum in rural areas (very fragrant gum).

N.B:

- (L): treatments made by leafs;
- (L.P): treatments made by leaf powder;
- (E.O): treatments made by essential oil;
- (F.O): treatments made by fixed oil;
- (R): treatments made by the resin;

### 3.6.2 Essential oil conservation

It is recommended to stock essential oils (photosensitive) in well-closed treated blue glass bottles, in order to protect them against light and air (oxidization) and in cool places in order to avoid their polymerization. The length of storage is generally 18 to 36 months (Saidi et al 2006).

**Table 5.** Results Analysis of mastic tree oil and olive oil from the same area (Laboratory of Tunisian Oil Office).

| Fatty acid | Mastic tree oil | Olive oil |
|---|---|---|
| Oleic C18 ' | 50 % | 69 % |
| Palmitic C16 | 27.2 % | 12.8 % |
| Linoleic C18 ' ' | 19.3 % | 12.9 % |
| Palmitoleic C16 ' | 1.7 % | 1.1 % |

## 4. Discussion

Evreïnoff (1948, in Rjaibi 1996) signalled the similarity of this oil with olive oil. In their compositions; they show the same constituent (oleic acid, palmitic acid) and their physical-chemical characteristics are so close that there is not any substantial distinction. Tunisian oil office confirms it in their analysis of the two oils.

The three important fatty acids that form the two types of oil are oleic acid, palmitic acid and linoleic acid. The other acids exist only in low percentages or in traces.

This table explains that there is a slight difference between mastic tree oil and olive oil. Percentages are different. There is less oleic acid in mastic tree oil and more palmitic acidic C16'; this explains the phenomenon of crystallization of mastic tree oil.

Comparing yields, 8 to 18% for mastic tree and 12 to 28% for olive tree (Laboratory of Tunisian Oil Office).

To produce a good quality essential oil, it is necessary to follow these recommendations:

- Note the Botanical Distilled Species: Latin name composed of the kind (*Pistacia*), and the species (*lentiscus*). The exact name will be *Pistacia lentiscus*.
- Define the Organ Producer: leaves, branches, or preferably new shoots…
- Identify the Biochemical Specificities: They depend for the same plant on the original country, soil, climate, altitude, sun light, exposure, etc. (Saidi et al 2006). Mastic essential oil has a very important antiseptic and bactericidal effect (Boukef et al 1984, in Rjaibi, 1996).
- Biological Quality: the raw material comes from the forest that doesn't undergo any amendment and is therefore of biological production.
- Essential Oils use Precautions: The investigation shows that the mastic tree essential oil is an active substance that can be dangerous if it is wrongly used. For this reason some precautions are necessary:
- Avoid its utilization by pregnant women, aged or fragile people and children if they are less than 3 years.
- Avoid its use on the mucous and around the eyes.
- Generally, mastic tree essential oil is used to dilute in vegetal oils like sunflower oil, soft almond oil and olive oil (Saidi et al 2006).

## 5. Conclusion

This study showed that the mastic tree has an important vegetal potential. This species is characterized by a biovolume of 1000 $m^3$ /ha, a total dry biomass of 800 kg /ha and a recovery of 600 $m^3$ /ha. The distillable part of the female trees is less important then the male ones. The distillable part is about 300 to 360 Kg/ha.

Mastic tree distillation (*Pistacia lentiscus*) showed that the output in essential oil remains constant with the cutting and turning for the female trees, but it's reduced to 25% after cutting for the male ones.

After drying, the essential oil yield decreases (60%) then increases to reach the volume of the first case (fresh material).

The investigation conducted with the urban and rural populations has shown some current uses of this species, particularly in traditional and veterinary medicine.

Actually, mastic tree essential oil comes only from the forest understory. Its essential oil is not valorised. However, the mastic tree fixed oil is widely known and is even very sought-after, considering its medicinal power.

Regardless of the importance of this species, the mastic tree is still not considered in forest Management and it is used only by the local population.

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In October 2007, EFIMED and the Universidad de Valladolid (Forestry School of Palencia) organised an international scientific seminar "Modelling, valuing and managing Mediterranean forest ecosystems for non-timber goods and services". This seminar brought together Mediterranean scientists from relevant disciplines (forest ecology, forest management, applied economics, operations research, and information technologies, etc) to discuss and present the latest scientific methods and results on modelling, valuing and managing non-timber products and services in different Mediterranean countries.

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ISSN 1237-8801
ISBN 978-952-5453-27-0