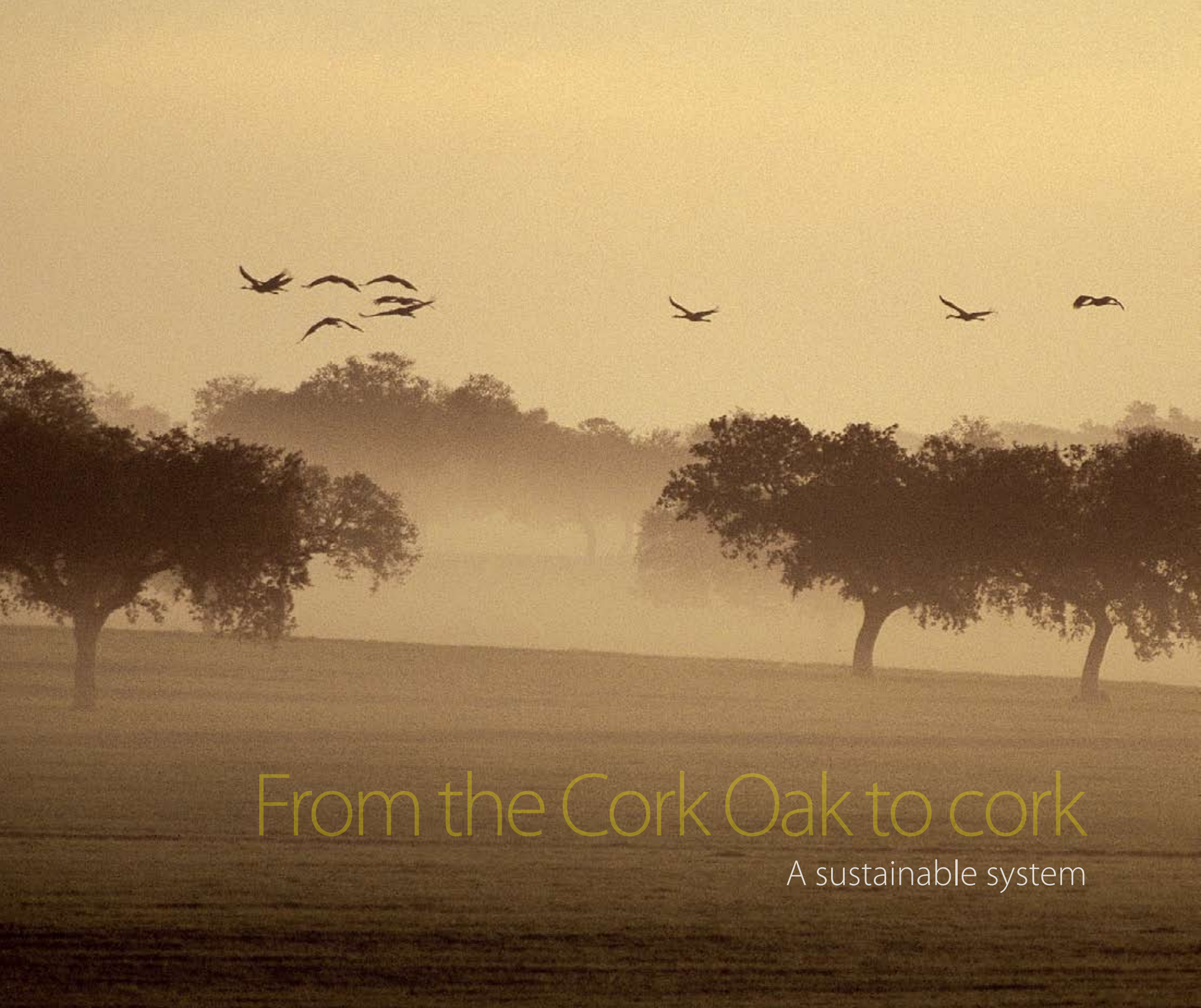

From the Cork Oak to cork

A sustainable system

CONTENTS

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"…When uncorking a bottle of a good wine or using any of the dozens of products made from natural cork, have you ever stopped to wonder where it comes from? If so, (let us know more about) the Cork Oak (*Quercus suber*), one of the most extraordinary trees on Earth. Whether fully clothed, in its arm-thick, fissured, light gray bark, or with brick red trunks recently undressed by a once-a-decade harvest of its corky clothing, the tree has great beauty, mystery, and charm, as writers and travelers have long recounted. The landscapes where it occurs have the same charm, or even more to those who know how to read them…"

(From "Introduction" in Aronson J., Pereira J.S., Pausas J.G. (eds.)
"Cork Oak Woodlands on the Edge: Conservation, Adaptive Management and Restoration".
Island Press, New York, 2009).

CORK: NATURAL, 100% RECYCLABLE AND REUSABLE. AN OPTION

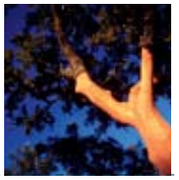
Cork is a natural product originating from the renewable bark of the Cork Oak, which Mother Nature planted essentially in southern Portugal. Home to an interminable variety of animal and plant species, the *montado* contributes to both regulating the hydrologic cycle and soil protection, avoiding desertification. The *montado* also fixates carbon dioxide, the main culprit for the planet's global warming. Recyclable and reusable, the motto "nothing is wasted, everything is transformed" applies itself to cork perfectly.

1 The Cork Oak is the only tree in the world with a bark – cork – that comprises such unique characteristics.

2 The Cork Oak has a long lifespan, living on average more than 200 years.

3 The first harvesting only takes place when the tree reaches 25 years of age. The subsequent harvestings occur every 9 years and are not harmful to the cork trees normal development.

4 The *montados* house a combination of unique or threatened species. The Iberian Lynx or the Imperial Eagle are but two examples. In addition, the Mediterranean Basin has between 15 to 25 thousand plant species, with more than half existing in this region.



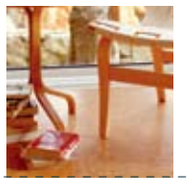
5 The cork forests contribute to carbon fixation. Less than 1,5 hectares of *montado* is necessary to mitigate the annual carbon dioxide emissions of an average vehicle.

IN FAVOUR OF PLANET EARTH.

6 Only after the 3rd harvesting, when the Cork Oak is around 40 years of age, does cork obtain the indispensable quality needed for the production of cork stoppers.

7 The cork stopper is the industries main product, representing around 70% of the total cork exploited worldwide. Portugal is the world's leading producer of cork stoppers.

8 Cork stoppers are 100% recyclable and can be reused in the manufacture of other products other than closures.



9 Cork is put to use 100%, nothing is wasted. The by-products from the production of cork stoppers are used for the manufacture of other products, such as: pavements, coverings and insulation; automobile gaskets; expansion joints for civil engineering; shoes; fashion accessories; fishing; musical instruments; sports; amongst many others.

10 With design and an investment in innovation, cork is used today in the manufacture of clothing, furniture, in decoration, amongst many other singular applications and with more yet to be discovered.

CURRENTLY, THE CORK OAK IS A TYPICAL SPECIES OF THE WESTERN MEDITERRANEAN REGION, OCCURRING SPONTANEOUSLY IN PORTUGAL AND SPAIN, BUT, ALSO, IN MOROCCO, IN NORTHERN ALGERIA AND IN TUNISIA.

THE CORK OAK – A MILLENARY TREE

· The Cork Oak – a millenary tree
· Cork Oak and cork – a singular relation
· *Montados* and *sobreirais* (Cork Oak forests) – a cultural heritage
· The Economic and Social Importance of the *montados*

The Cork Oak belongs to a small sub-group that embodies European and Asian species– the group Cerris.

The first trees identified as Cork Oaks occurred millions of years ago.

THE CORK OAK – A MILLENARY TREE

The ecosystems, besides providing us with goods and services directly valued in the market (for example, food, fibre) also generate environmental services essential to the survival of man and whose direct valuation in the market is difficult and frequently non existent or carried out by indirect means. Biodiversity conservation, the regulation of the hydrologic cycle, soil protection and carbon fixation are examples of services generated by forest ecosystems including the *montados* and Cork Oak forests (*Quercus suber L.*) in Portugal and the Mediterranean Basin.

The Cork Oak has green leaves all year round (it is an evergreen tree) and has a very special bark – the cork. Included in the oak genus (*Quercus spp.*), a group of species with common affinities and origin. The Cork Oak belongs to a small sub-group that embodies European and Asian species– the group Cerris. Their closest relations are the Eastern Oaks of the Mediterranean Basin (for example, *Quercus cerris, Quercus trojana, Quercus macrolepis*).

The first trees identified as Cork Oaks occurred millions of years ago. Since then, several episodes of climatic changes have occurred affecting the vegetation. Particularly interesting is the period that began around 1.8 million years ago – the Pleistocene - characterized by alternating periods of extreme cold (glacial eras) with warmer inter-glacial periods. These events decisively influenced the geographical distribution and the genetic diversity of the Cork Oak. The cold forced the Cork Oak to take refuge in more benign climatic areas, whilst the amenity of the inter-glacial periods allowed for its territorial expansion. The warming at the end of the last glacial period, around 10 thousand years ago, allowed the Cork Oak to colonize its present distribution area.

Illustration 1 – Cork Forest Area Worldwide

Source: APCOR. Year: 2007

Currently, the Cork Oak is a typical species of the Western Mediterranean region, occurring spontaneously in Portugal and Spain. More than half of this area is located in the Iberian Peninsula.

Currently, the Cork Oak is a typical species of the Western Mediterranean region, occurring spontaneously in Portugal and Spain, but, also, in Morocco, in Northern Algeria and in Tunisia. In addition, it is found in more restricted areas in the south of France and on the west coast of Italy, including Sicily, Corsica and Sardinia. The total occupied area is currently around 1,43 million hectares in Europe and 0,85 million hectares in Northern Africa. More than half of this area is located in the Iberian Peninsula (**Illustration 1, Chart 1, 2 and 3**).

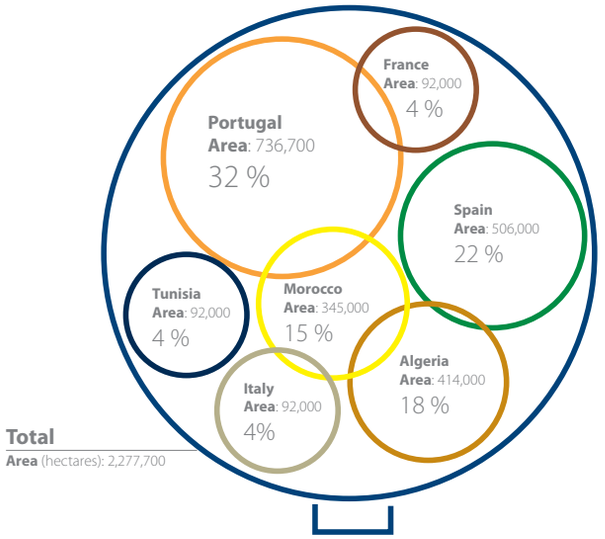


Chart 1- Cork Forest Areas

Source: Direcção Geral das Florestas DGRF (National Forestry Authority) and APCOR Year: 2006

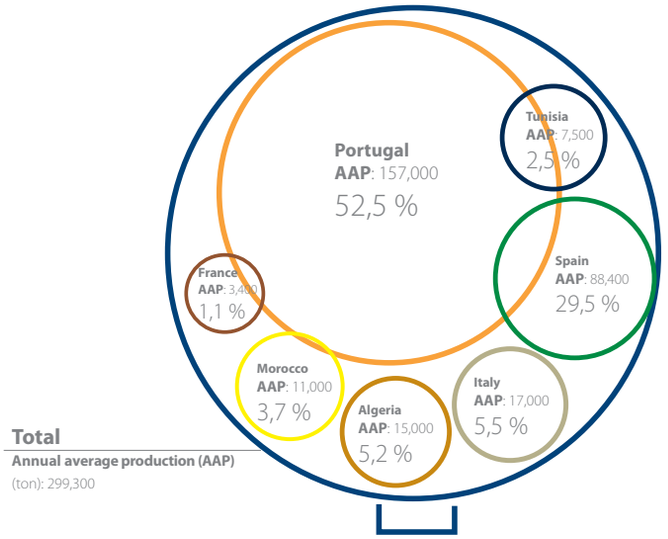
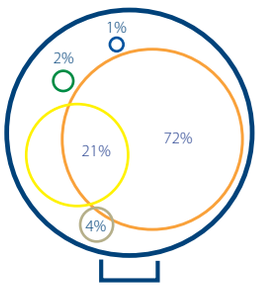


Chart 3 – Cork Production

Source: APCOR Year: 2007



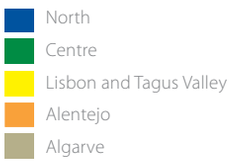


Chart 2 – Cork Production in Portugal by region (%)

Source: DGRF. Year: 2006

CORK OAK AND CORK – A SINGULAR RELATION

In vast regions of Southern Europe and Northern Africa, the landscape is characterized by the presence of Cork Oaks. It is a tree that does not pass unnoticed. The dry coloured scenery of the Mediterranean summer is dotted green by the thick crowns of this tree.

Being an evergreen tree it has pros and cons in a seasonally dry climate. One of the advantages is that the tree it is able to carry out photosynthesis for longer throughout the year, something that is not possible for deciduous trees, which lose their leaves during winter. On an inconvenience level, during periods of food scarcity the presence of green leaves becomes inviting for many herbivores, particularly insects. To resist the herbivores the plants developed chemical defences (such as anti-nutritive chemical compounds) and structural (such as leathery and thorny leaves) to protect themselves. The relatively dense and thick leaves are known as sclerophyllous (from the Greek, *skleros* = hard and *phyllon* = leaf). The Cork Oak leaves are, however, less dense and less tolerant to climatic extremes than the leaves of other evergreen trees, for example, Holm Oak (*Quercus rotundifolia* = *Quercus ilex subsp. ballota*) that frequently coexists with the Cork Oak.

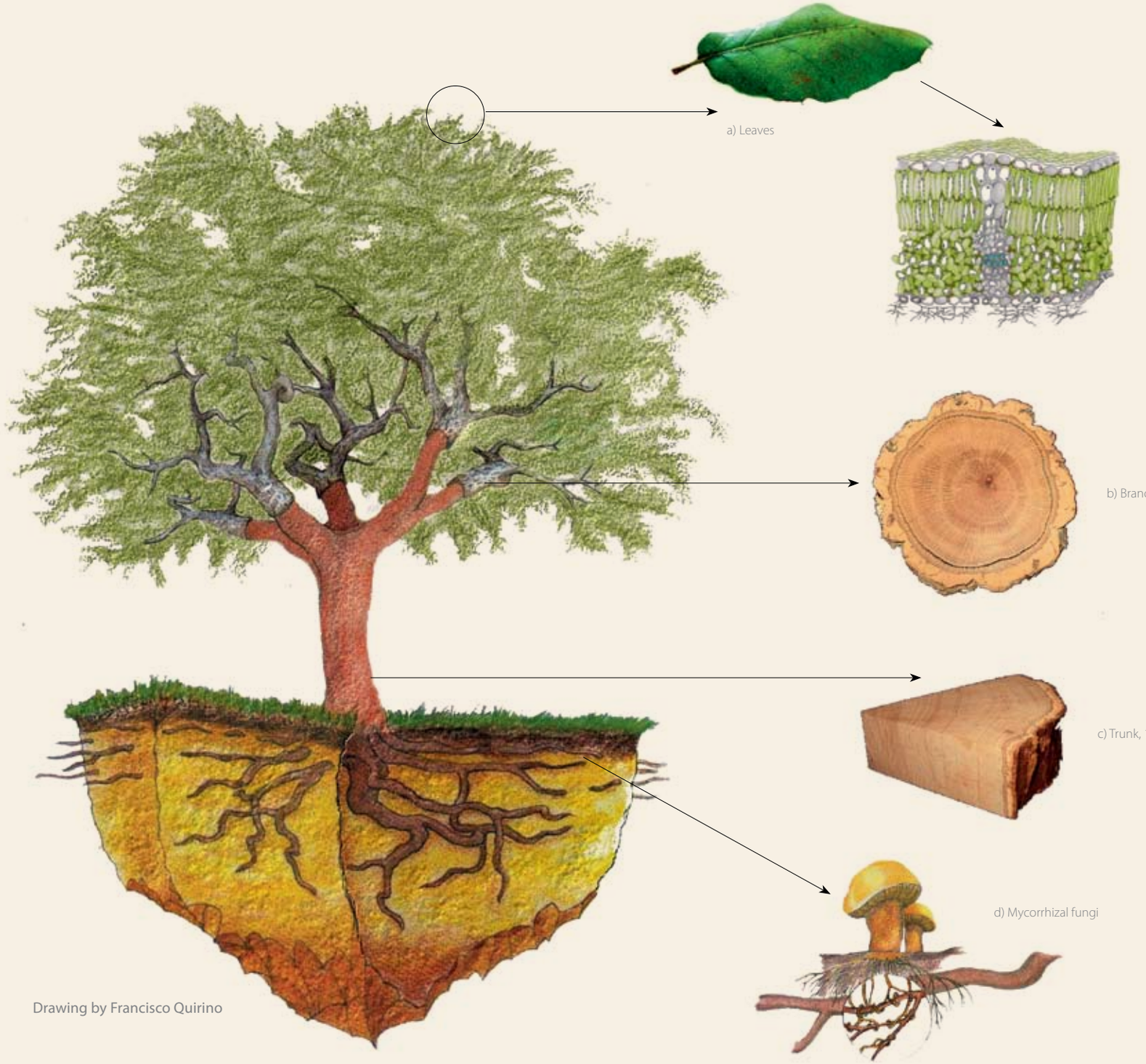
The Cork Oak maintains sufficient hydration due to a system of roots that can reach several meters in depth.

The Cork Oak's most interesting particularity is the outer bark production, formed by an elastic, impermeable and good thermal insulating tissue – the cork.

In a Mediterranean type climate evergreens have to survive the harsh summer drought. The Cork Oak is, well adapted to the typical water scarcity of the Mediterranean summer. During summer, the Cork Oak and other trees in the Mediterranean climatic region reduce water losses through their leaves (that is, transpiration), as well as metabolism and growth. The loss of water is regulated through the stomata - "pores" - located in the lower epidermis of the leaves that control the gas exchanges: the incoming of CO_2, for photosynthesis, and the loss of water vapour during transpiration. But the stomata are not completely watertight and the tree may dehydrate throughout time. For a tree to survive, however, it can not dry up. The Cork Oak maintains sufficient hydration due to a system of roots that, besides their horizontal extension, can reach several meters in depth. This allows for the extraction of water from the subsoil and even from water tables. During summer more than 70% of the water transpired by Cork Oaks may originate from the deepest soil and subsoil layers.

The Cork Oak's most interesting particularity is the outer bark production, formed by an elastic, impermeable and good thermal insulating tissue – the cork. Cork is composed of dead cells with walls that are impermeable due to a chemical compound named **suberine**. All the trees produce layers of suberized cells as a means of protection, but only the Cork Oak is able of "constructing" its outer bark by adding annual rings of cork resulting from an activity carried out by a combination of mother cells - the phelogen (**Illustration 2**). The homogeneity of cork is the result of the Cork Oak's phelogen maintaining its activity throughout the tree's lifespan. This contrasts with the other trees, where each phelogen has a short life span.

Illustration 2 – The Cork Oak: (a) Leaves are thick, with palisade cells and abundant microscopic stomatal under the leaf. Photosynthesis, which is the basis of all plant production occurs in the leaves; (b) Cork is a bark that persists on the tree; (c) When harvested, the Cork Oak's phelogen regenerates and produces new cork layers; (d) The Cork Oak has roots that grow in depth but, also, an abundance of roots in the soil's surface which, at times, can be associated with fungi (mycorrhizal).



a) Leaves

b) Branch with cork

c) Trunk, 1 year after cork stripping

d) Mycorrhizal fungi

Drawing by Francisco Quirino

The uniqueness of cork may have an adaptive value, that is, it probably improved the survival of the Cork Oak throughout evolution. The physical attributes of cork, namely its good insulating properties, can protect Cork Oak against fire. After a fire, while many of the other tree species merely regenerate from seeds (as, for example, the Maritime Pine) or resprout from the base of the tree (as, for example, the Holm Oak) the Cork Oak branches, protected by cork, quickly resprout and recompose the tree canopy. The quick regeneration of the tree seems to be an advantage compared to other species that, after a fire, return to an initial stage of development. Cork may have been the Cork Oak's evolutionary answer in an environment where fire was an important ecological factor.

The harvesting of cork without damaging the tree is another originality that results from the anatomy and functioning of the Cork Oak's periderm. When cork is harvested, at the end of spring and during summer, it is essential that the cells (phelogen) responsible for its production maintains their activity and continue to divide themselves. In these conditions, cork can be extracted from the tree without damaging it. This is only possible when there is water available in the plant, which is why it is important, especially in the dry Mediterranean summer, that the Cork Oak maintain its tissues hydrated.

The physical attributes of cork, namely its good insulating properties, can protect Cork Oak against fire.

THE NATURA 2000 NETWORK, CLASSIFIES *MONTADOS* (HABITAT 6310) AND CORK OAK FORESTS (HABITAT 9330) AS VERY IMPORTANT FOR THE CONSERVATION OF BIODIVERSITY.

Biodiversity

The cork forests are rich in fauna and flora, constituting biodiversity hotspots.

COLLABORATION
COLABORAÇÃO

Carbon Sequestration

The cork forests can fixate 5,72 t of CO_2 per hectare/year. Less than 1,5 hectares of *montado* is necessary to compensate for the annual carbon dioxide emissions of an average vehicle.

COLLABORATION
COLABORAÇÃO

MONTADOS AND *SOBREIRAIS* (CORK OAK FORESTS) – A CULTURAL HERITAGE

In the western Iberian Peninsula, the Cork Oak is found naturally in mixed plant communities, or Cork Oak forests. In addition to the Cork Oak, these communities may include deciduous oaks – such as the Portuguese Oak (Quercus faginea), the Pyrenean Oak (Quercus pyrenaica) or the Pedunculate Oak or English Oak (Quercus robur); the Maritime Pine (Pinus pinaster) or the Umbrella Pine (Pinus pinea); and, also, along water margins, species such as Willows (*Salix spp.*), the Alder (*Alnus spp.*), the Ash tree (*Fraxinus spp.*) and poplars (*Populus spp.*). Occuring species depend on management and soils, but frequently include Rockroses (*Cistus spp.*), Brooms (*Cytisus spp., Retama spp.*), Heathers (*Erica spp.*), Myrtle (*Myrtus spp.*), Mastic (*Pistacia lentiscus*) and the Strawberry Tree (*Arbutos unedo*). Herbs are usually at high diversity, and include leguminous plants as Clovers (*Trifolium spp.*), Bird´s foot (*Ornithopus spp.*), Medick (*Medicago spp.*); and the grasses such as the Ryegrass (*Lolium spp.*), Oats (*Avena spp.*), Cocksfoot (*Dactylis glomeratum*) but also, forbs as Long plantain (*Plantago lanceolata*) or Common sorrel (*Rumex acetosa*).

The Iberian Peninsula Cork Oaks , frequently constitute stands of a single species, with a tree cover which, structurally, reminds us of savannas. These stands may have occurred in prehistory, resulting from the use of fire by man, as happens, still today, in savannas. There is evidence of the continuity of these stands throughout history, making them part of the cultural heritage of the Western Mediterranean and in regions, such as the South-western Iberian Peninsula or Sardinia, they even constitute part of the regions identity.

Many of the current Cork Oak stands appeared from mid XIX century due to the increasing value of cork as well as demand and, the search, in cities undergoing expansion, of livestock products as pork which were produced in the *montado* (pasture and acorn feeding). Although the production of cork may be more specialized today than in the past, the *montados* form **cultural landscapes** – that is, systems that resulted from human activity for the utilization of diverse resources: cork pastures and agricultural cultivations that frequently coexist in the same area and confer a silvopastoral characteristic to the *montado*.

The Iberian Peninsula Cork Oaks, frequently constitute stands of a single species, reminds us of savannas.

The *montados* form cultural landscapes – that is, systems that resulted from human activity for the utilization of diverse resources: cork pastures and agricultural cultivations.

The Cork Oak's distribution area reaches 736 700 hectares, that is, a third of the total distribution of the species in the world and 23% of the Portuguese forest – representing the dominant species in Portugal.

Cork Oak *montados* and forest originate 12 thousand direct job posts in the industry, 6500 job in forest exploitation and, indirectly, thousands of employment positions related to other Cork Oak forest products.

Reforestation has contributed to an annual increase of cork forest of 1% in Portugal.

Cork Oak plantations of approximately 150 thousand hectares were made in both Portugal and Spain (Source: APCOR).

THE ECONOMIC AND SOCIAL IMPORTANCE OF THE *MONTADOS*

Both the export of cork products and the consumption of other products represent very high values in almost all countries where the Cork Oak occurs. Eighty percent of global cork product exports come from the Iberian Peninsula. Approximately 60% of the world's exports originate from Portugal, where according to the Portuguese National Forestry Inventory (2006), the Cork Oak's distribution area reaches 736 700 hectares, (that is, a third of the total distribution of the species in the world and 23% of the Portuguese forest – representing the dominant species in Portugal).
Cork oak has a high economic and social importance in Portugal: Cork Oak *montados* and forest originate 12 thousand direct job posts in the industry, 6500 job in forest exploitation and, indirectly, thousands of employment positions related to other Cork Oak forest products (livestock farming, restaurants, tourism, etc.), contributing to 2,3% of the total annual national export and 30% of the combined Portuguese forestry exportations. The economic value of Cork Oak is also related to other incomes associated with the cork forest: hunting, honey, mushrooms and livestock farming.

The area of Cork Oak stands in Iberian Peninsula has increased consistently throughout the XX century, having stabilized thereafter. Recently there has been a slight increase due to reforestation and other protective measures, which hinder the felling of Cork Oaks or the conversion of Cork Oak forests to other uses. In the last decades, reforestation has contributed to an annual increase of cork forest of 1% in Portugal. Cork Oak plantations of approximately 150 thousand hectares were made in both Portugal and Spain (Source: APCOR). In Spain, the increase in cork forests was accompanied by an increase in the tree density of stands. On the other hand, in some cases, a decrease in tree density has occurred because of old age and death of adult trees. In recent years, forest fires, severely affected the Portuguese forests. However, the Cork Oak *montado* burns less than forest stands of other species such as Maritime Pine or Eucalyptus. The areas of *montado* that were affected by fires were compensated, by reforestation, and by the natural recovery of burnt areas.

THE IBERIAN LYNX THE FELINE MOST CRITICALLY THREATENED IN THE WORLD, FINDS THE *MONTADOS*, CORK AND HOLM OAK FORESTS TO BE ITS PREFERED HABITAT.

Programa de Conservación Ex-Situ del Lince Ibérico

Iberian Lynx

THE HIGH BIODIVERSITY OF THE *MONTADO*

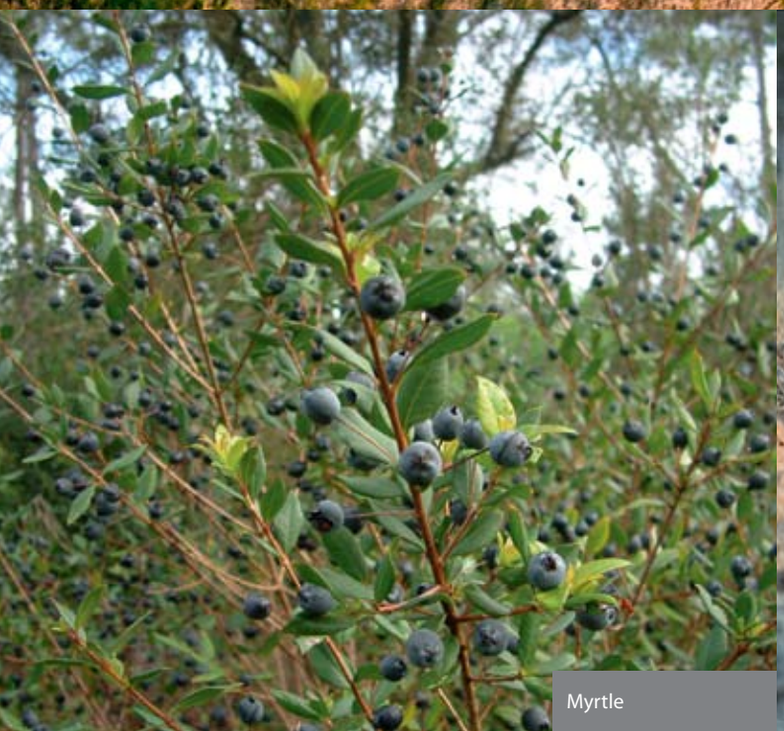
THE HIGH BIODIVERSITY OF THE *MONTADO*

Mediterranean ecosystems are particularly rich in species of fauna and flora, constituting biodiversity hotspot. The Mediterranean Basin has between 15 to 25 thousand plant species, a number of species much higher than found in the rest of Europe. More than half of these species are endemic to the Mediterranean - endemic species. Cork Oak is one of these endemics. In addition *montados* and Cork Oak forests are important reservoirs of biological diversity. The Natura2000 network, a pan-European network of classified nature conservation areas, classifies *montados* (**habitat 6310**) and Cork Oak forests (**habitat 9330**) as very important for the conservation of biodiversity.

The *montados* form heterogeneous habitats, with varying age and height, interspersed with grasslands and, more rarely, cereal crops, with varying tree density (from 30 or 40 trees to over 100 trees per hectare).
Cork Oak stands have vertical and horizontal diversity (the "mosaic" of use), which favours various species of fauna and flora because of different niches it creates. For instances, microclimate and soil fertility characteristics vary between areas influenced by the crowns and the open spaces. Despite being managed as agro-silvo-pastoral systems with a conditioned multifunctionality, *montados* are also constituted by native vegetation elements. The longevity of the trees and their structural persistence contributes to the high biodiversity of the *montados*.

Miguel Nuno Bugalho

Deer



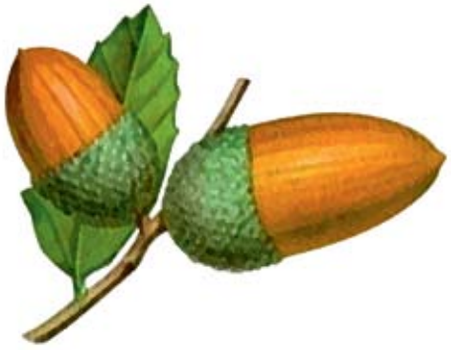
Myrtle

Miguel Nuno Bugalho

Red-legged Partridge

The Mediterranean Basin has between 15 to 25 thousand plant species.

The Natura2000 network, classifies *montados* (habitat 6310) and Cork Oak forests (habitat 9330) as very important for the conservation of biodiversity.



Acorn

Strawberry tree

GRASSLANDS WITHIN *MONTADO* AREAS ARE ALSO, VERY RICH IN HERBS SPECIES. FOR INSTANCE, MORE THAN ONE HUNDRED SPECIES WERE RECORDED IN PLOTS OF 0,1 HECTARES.

The majority of the herbaceous species are annual, that is they grow, produce seed and die within a period of a year, passing the dry summer period in the form of a seed, buried in the soil: a beautiful adaptation to the Mediterranean climate which contributes to different plant communities over the years. Environmental heterogeneity caused by the canopy of the trees induces different specie composition, contributing to high plant diversity. For example, Portuguese endemisms as the grass *Avenula hackelii* or the legume *Ononis hackelii* may occur in the *montados*.

Miguel Nuno Bugalho

Rockroses

João Nunes da Silva

Short-toed Eagle

Jorge Rodrigues

Great spotted cuckoo

Faísca

Black-shouldered Kite

João Nunes da Silva

Corn Bunting

In addition to high plant diversity, structural and biological characteristics give *montados* an aptitude for escape, cover, nidification and foraging areas for unique species of fauna, some with a protection status. The Iberian Lynx (Lynx pardinus), the feline most critically threatened in the world, finds the *montados* cork and holm oak forests to be its prefered habitat. The Imperial Eagle (*Aquila adalberti*), a bird of prey in danger of extinction, nidifies in the trees and hunts in open areas of *montado*.

Other species such as the Wildcat (*Felis sylvestris*) or birds of prey like the Short-toed Eagle (*Circaettus gallicus*), the Booted Eagle (Hierattus pennatus) or the Bonnelli Eagle (*Hieraaetus fasciatus*) nidify in the *montados*. The crowns constitute an important shelter during nidification season or hiding coverage throughout the year. The shrubs, typical of many *montados* (*Cistus spp.*, Strawberry Tree, Myrtle, Heathers), besides being rich in tree species are also an essential habitat for species of conservation interest (for example some species of warblers (*Sylvia spp.)*).

The Iberian lynx, the feline most critically threatened in the world, finds the *montados* cork and holm oak forests to be its prefered habitat.

Drawing by Francisco Quirino

Miguel Nuno Bugalho

Wild Hare

Miguel Nuno Bugalho

Fox

A large diversity of insects form, in the *montado*, the base of a diverse feeding network (**Illustration 3**). The young Cork Oak leaves are very desirable as food to some insects. Some species such as the Gypsy Moth (*Lymantria dispar*), the Lackey Moth (*Malacosoma neustria*) or the Tortrix Moths (*Tortrix viridiana*) can even cause heavy tree defoliation in certain years.

Other organisms like fungi (*Basydiomycetes*) occur in *montados*. These species are important for the decomposition of organic matter in the soil. Other species, however, are pathogenic and dangerous to the *montado* plants. Many species are mycorrhizal (**Illustration 3**) - that is, they associate symbiotically with the tree roots obtaining organic carbon from the tree and helping it absorbing soil nutrients. For the Cork Oak, mycorrhizal are essential. Without them the trees would find difficulty in assimilating phosphorous and other minerals from the poor soils where they occur. Many mushrooms are edible, some having great gastronomic value. Mushroom picking is an important activity in many *montados* in the Iberian Peninsula.

Other organisms like fungi occur in *montados*. Many mushrooms are edible, some having great gastronomic value.

Illustration 3 – The *montado* hosts a large variety of animal and plant species that form food chains.

THE FORESTS PERFORM A FUNDAMENTAL ROLE IN THE REGULATION OF THE WATER BALANCE. THE INFILTRATION PROCESSES AND THE SUPERFICIAL WATER EROSION, FOR EXAMPLE, ARE INFLUENCED BY THE PRESENCE OF THE TREES AND THEIR RADICULAR SYSTEMS.

HYDROLOGIC REGULATION AND SOIL CONSERVATION

· Hydrologic Regulation and Soil Conservation
· Carbon sequestration

By promoting the infiltration of rain and preventing soil erosion, the *montados* contribute to water cycle regulation.

The *montados* by playing a role in soil conservation and protection are important for combating **desertification**.

HYDROLOGIC REGULATION AND SOIL CONSERVATION

The forests perform a fundamental role in the regulation of the water balance. The infiltration processes and the superficial water erosion, for example, are influenced by the presence of the trees and their radicular systems. The tree crowns intercept more rain water than the lower vegetation and "channel" it to the soil beneath the tree as it flows down the tree trunk and drips from the foliage. Frequently the soil beneath the crowns is more permeable and has a much larger capacity to retain water than the uncovered soil. Isolated trees in the *montado* function as rain interception wicks that lead to underground water retention.

Soil conservation is a fundamental aspect of the *montados* sustainability. In many cases, especially in the climatic regions of the Mediterranean, soil fertility is dependant on the organic matter, resulting from the decomposition of organic waste (for example, leaves, branches, dry grass). The soil richer in organic matter is characterized for having better infiltration, water storage, nutrient retention, aeration and root growth capacities. In the case of the *montado*, the leaves are renewed annually. The old leaves (as well as small branches, fruits and excrements from animals' habitating the *montado*) fall on the soil where they decompose and contribute to soil organic matter and nutrients. The decomposition of plant and animal debris returns nutrients that, in part, were captured by the roots in deeper soil horizons, in a process of nutrient translocation from the soil depth to the surface. The main contributor of organic matter in the soil is the thin roots that proliferate close to the soil surface and have a short lifespan.

The crowns are also important for soil protection from the direct impact of rain that may cause erosion. The diverse forms of plants covering the *montados*, insures, through their coverage and above all their root systems, protection against soil erosion, namely in areas of high slopes. The area underneath the crowns is also rich in nutrients (for example holding about 50% more nitrogen) and carbon (about 60%) than in the uncovered soil. By promoting the infiltration of rain and preventing soil erosion, the *montados* contribute to water cycle regulation, an environmental service particularly important in Mediterranean climatic areas where water is, a scarce resource (a situation that may aggravate in the future).

In some regions of Northern Africa, the elimination of trees has lead to irreversible soil degradation processes and physical desertification. The *montados* by playing a role in soil conservation and protection are important for combating **desertification**. This is particularly significant in Northern Africa where forest degradation, due to demographic pressure and climate, accentuate the risks of desertification. The cork forests, due to their potential economic value may also be crucial in forming a barrier against desertification.

Near 1,5 hectares of *montado* with a tree coverage of, at least, 30 to 40%, are enough to compensate for the annual carbon dioxide emissions of an average vehicle.

CARBON SEQUESTRATION

The scientific community today acknowledges that gas emissions, responsible for the greenhouse effect (for example, methane or carbon dioxide), are the result of human activities, responsible for global warming which affects the climate. Through photosynthesis, trees and forests, absorb carbon dioxide which is transformed in organic tissues whose mass is comprised of roughly 50% carbon. The net carbon retention in the ecosystem depends upon the balance between gains (photosynthesis) and losses (respiration of all the organisms in the ecosystem). In forests, the carbon stored (retained) in perennial plant tissues (wood and cork as well as in soil organic matter) subtract from the carbon dioxide of the atmosphere, contributing to the mitigation of greenhouse gases emitted by human societies. The Cork Oak and the *montados* are not different from other forests: long-living trees (for example, hundreds of years) may sequester carbon for long periods.

Even though low tree density may limit carbon retention in the *montados*, as compared to other forests, various studies carried out in Portugal have shown the carbon assimilating and retention capacity of these systems. For example, on average (2003-2006) the annual retention of carbon in a *montado*, with approximately 30% tree coverage, was 88 g C per m^2 (or rather 3,2 tonnes of CO_2 per hectare and per year). Taking into account that this average includes a very dry year (2005), one may consider that the normal annual retention does not differ much from a same type forest (example *Quercus douglassi* with 40% tree coverage) in California, this is, 156 g C per m^2 and year (or rather, 5,72 t CO_2 per hectare and year), or from Maritime Pine stands, in Alcácer do Sal, 150 g C per m^2 and year (or rather, 5,5 t CO_2 per hectare and year).

According to these numbers, near 1,5 hectares of *montado* with a tree coverage of, at least, 30 to 40%, are enough to compensate for the annual carbon dioxide emissions of an average vehicle. With good forestry management practices and a higher density of healthy trees, higher annual carbon retention values can be admitted. The contrary occurs in cases where tree mortality exists or where the soil suffers frequent mobilization. In fact, soil mobilization (for example to eliminate shrubs) prompts the accelerated decomposition of organic matter and the emission of carbon dioxide into the atmosphere through microbial respiration, leading to a loss of carbon from the ecosystem.

Carbon sequestration = 5,7 t
CO_2 per hectare/year

CORK STOPPERS ARE NATURAL PRODUCTS WHOSE EXTRACTION, BESIDES NOT AFFECTING THE ECOSYSTEM PROCESSES, ALLOW *MONTADOS* AND CORK OAK FORESTS TO BE MANAGED AS MULTIPLE USE SYSTEMS ABLE TO PERFORM ESSENTIAL ECOSYSTEM SERVICES.

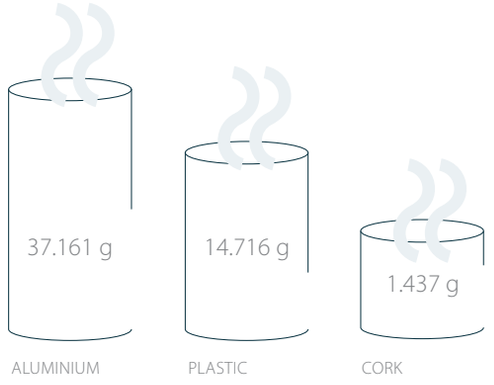
THE CORK INDUSTRY AND THE ENVIRONMENT

- The sustainable management of the *montados*
- The cork industry and the environment
- The Cork Oak and the *montado* at a glance

THE SUSTAINABLE MANAGEMENT OF THE *MONTADOS*

For *montados* to maintain their cork production capacity and provide the referred environmental services it is necessary that they are adequately managed. Certification is a mechanism that assures sustained management by compliance with pre-established criteria. Systems such as the Forest Stewardship Council (FSC) certify forest management systems, like the *montado*, by the fulfilment of environmental, social and economical character criteria. Currently, there are in Portugal approximately 15 thousand hectares of FSC certified *montado* and forestry associations have officially committed to reaching 150 thousand hectares of certified *montado* in the near future.

Illustration 4 – CO_2 emissions (g)/1000 stoppers



THE CORK INDUSTRY AND THE ENVIRONMENT

Approximately 300 thousand tonnes of cork are harvested annually, with Portugal being responsible for around 52,5% of the world's cork production. Most of this cork (68%) is transformed into stoppers. The manufactured cork products will continue to retain carbon (half weight of a natural stopper when dry and approximately 1,7g of carbon per natural stopper or 6,2g of CO_2) during a fairly long period, according to the waste treatment schemes of each country and region. This role only terminates when cork is burnt and the carbon is returned to the atmosphere in the form of CO_2.

But what happens when the whole production process, stopper distribution and usage is taken into account? Will this process be a source of greenhouse gases, thus minimizing the carbon sequestration (sink effect) of cork and *montados*? A study carried out by **PricewaterhouseCoopers/ Ecobilan**, promoted by Corticeira Amorim, on the lifecycle of the cork stopper in comparison with aluminium and plastic stoppers concluded that, relative to greenhouse gas emissions, the production and usage of each plastic stopper releases 10 times more CO_2 than a cork stopper and presented CO_2 emissions for the aluminium stopper 26 times superior to that of cork (**Illustration 4**). It is also possible to reduce the "carbon footprint" of cork products by increasing the recycling of raw material (for example by recycling stoppers), increasing the renewable energy quota, improving the use of energy efficiency and diminishing the consumption of fossil fuels in transport, industrial processing and distribution. According to the above mentioned study, cork stoppers have environmental advantages in comparison with alternative closures if one considers the consumption of natural resources, the emissions of gas and particles into the atmosphere, water pollutant emissions and waste production.

There are in Portugal approximately 15 thousand hectares of FSC certified *montado* and a commitment to reach 150 thousand hectares in the near future.

A natural cork stopper retain 6,2g of CO_2.

The production and usage of each plastic stopper releases 10 times more CO_2 than a cork stopper and presented CO_2 emissions for the aluminium stopper 26 times superior to that of cork.

Cork stoppers have environmental advantages in comparison with alternative closures if one considers the consumption of natural resources, the emissions of gas and particles into the atmosphere, water pollutant emissions and waste production.

Assuming that 10 hectares of disperse *montado* is necessary to produce 1 tonne of cork stoppers, this area of *montado* will retain roughly 32,2 t of CO_2 per year. This value corresponds to the annual emission of CO_2 into the atmosphere of about 7 vehicles, with an average emission of 182g CO_2 per km and running 25 thousand kilometres annually.

Cork harvesting has also a minimum effect in the *montados'* carbon *stock* and balance. In fact, it is estimated that cork harvested every 9 years (or longer intervals in other regions) represents approximately 4% of the total trees' biomass production within the same period. This means that the exploitation of cork in the *montado* does not affect the ecosystem carbon sink role, contrary to the forests exploited for wood whereby the trees, carbon reservoirs, are felled. Assuming that 10 hectares of disperse *montado* is necessary to produce 1 tonne of cork stoppers, this area of *montado* will retain roughly 32,2 t of CO_2 per year.This value corresponds to the annual emission of CO_2 into the atmosphere of about 7 vehicles, with an average emission of 182g CO_2 per km and running 25 thousand kilometres annually. Although the exact figure cannot be easily calculated due to spatial and interannual variation in carbon sequestration, 1 tonne of cork stoppers may leave behind a large amount of carbon retained in its forest of origin.

THE CORK OAK AND THE *MONTADO* AT A GLANCE

The Cork Oak is an emblematic tree from the Mediterranean Basin, particularly South-western Europe and Northern Africa. It is an essential component of a combination of semi-natural ecosystems, of which the *montados* are a paradigm. Multifunctional systems of land use, they integrate cultural landscapes of high historic and social value. Cork Oaks are reasonably tolerant to drought, have deep root systems that capture water from the soil depths, and are able to face the stress of the dry and hot Mediterranean summers. Their leaves are reactive to drought, with "pores" (stomata) that close, reducing water loss by transpiration during the dry seasons. In addition to cork and products, such as hunting or pastures, the *montados* and Cork Oak forests perform important tasks in regulating the water cycle and in soil conservation, being important in combating desertification. Because they normally constitute heterogeneous and resilient habitats, *montados* and Cork Oak forests house high levels of biodiversity. Just like other forests, the *montados* and Cork Oak forests function like carbon sinks, being able to contribute to the mitigating greenhouse gas effects. Preliminary estimates substantiate the idea that cork that is harvested every 9 years represents an insignificant quantity of the *montados* carbon storage. Cork stoppers are natural products whose extraction, besides not affecting the ecosystem processes, allow *montados* and Cork Oak forests to be managed as multiple use systems able to perform essential ecosystem services. Careful management and adequate added value of the services rendered by these systems are essential for the sustainability and benefit maintenance generated for the society.

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