



MANAGEMENT of Natura 2000 habitats

* Macaronesian laurel forests (*Laurus*,
Ocotea)

9360

*Directive 92/43/EEC on the conservation of natural habitats and
of wild fauna and flora*

The European Commission (DG ENV B2) commissioned the Management of Natura 2000 habitats. 9360
*Macaronesian laurel forests (*Laurus, Ocotea*)

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ISBN 978-92-79-08341-9

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Guimarães A. & Olmeda C. 2008. Management of Natura 2000 habitat. 9360 *Macaronesian laurel forests (*Laurus, Ocotea*). European Commission

This document, which has been prepared in the framework of a service contract (7030302/2006/453813/MAR/B2 "Natura 2000 preparatory actions: Management Models for Natura 2000 Sites"), is not legally binding.

Contract realized by: ATECMA S.L. (Spain), COMUNITÀ AMBIENTE (Italy), DAPHNE (Slovakia), ECOSYSTEMS (Belgium), ECOSPHERE (France) and MK NATUR- OCH MILJÖKONSULT HB (Sweden).

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This model also includes management recommendations for another habitat closely associated with 9360: **4050 *Endemic Macaronesian heaths**



Laurel forest stand in Barranco de Nieto (Tenerife). Photo: Andy Gillison



93 - Mediterranean sclerophyllous forests

EUNIS Classification:

G2.3 - Macaronesian (*Laurus*) woodland

* Priority habitat

Summary

Once widespread throughout mainland Europe, the humid to hyper-humid evergreen forests known as laurel forests were driven close to extinction by advancing glaciers. Now restricted to the cloud belt of the Macaronesian islands, they grow in deep soils at between 500 and 1,500 m.

Laurel forest is closely related to Macaronesian endemic heaths (4050), another priority habitat of the Habitats Directive characteristic of the region. Laurel forests are dominated by tree and shrub species with laurel-shaped leaves, whereas in Macaronesian heaths ericaceous species predominate. As both types are interrelated and often intermixed in natural areas, they are often subject to joint management.

Macaronesian laurel forests have been intensively transformed since the fifteenth century, when the original forest area was largely razed to create farmland and degraded due to forest exploitation and livestock farming. Significantly reduced nowadays, in some areas habitat is still being degraded due to exploitation and livestock. In some cases, habitat reduction has led to fragmentation, threatening habitat diversity and leading to species extinction. Other current threats are the spread of exotic species, a major concern in the Azores and Madeira, and forest fires, especially serious in the Canary Islands.

As a general rule, mature, well developed laurel forests with sound ecological status should not be subject to active management, but rather left to evolve as naturally as possible. Many, however, are highly degraded, which justifies the need for active management to promote restoration. The recent abandonment of agricultural land has also allowed the recovery of some areas that are currently at a secondary succession stage; proper management will boost habitat recovery. Care should be taken regarding Macaronesian endemic heaths for, in many cases, they occur as succession phases in laurel forest development. Decisions regarding whether they should be managed to maintain their own features or to evolve towards a laurel forest habitat have to be taken on a case by case basis.

Where necessary, the type of management is chosen according to the degree of habitat development and to local features. The most common situations are: selective cuttings to improve regeneration in stands that have been heavily exploited, conversion of forest plantations into laurel forests, eradication and control of exotic invasive species and recovery of specific threatened species. Ongoing long-term studies involving representative permanent plots further knowledge of laurel forest dynamics.

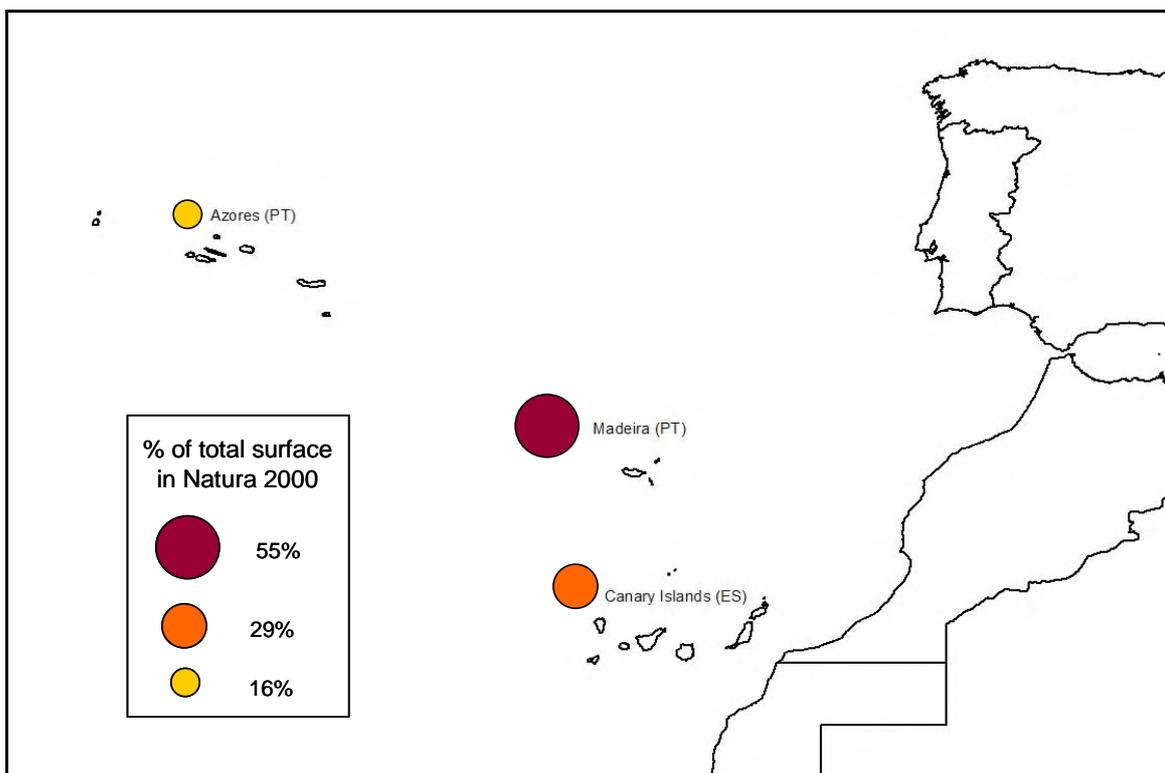
1 Description of habitat and related species

The Macaronesian laurel forests, also called laurisilva, are humid to hyper-humid evergreen forests of the cloud belt of the Macaronesian islands. Tree species with laurel-shaped leaves are predominant, forming a dense canopy up to 40 m high that can be hardly trespassed by light, which results in scant vegetation in the understory.

This habitat is closely associated with another habitat typical of the Macaronesian region, the endemic Macaronesian heaths (*4050). Both communities have similar species composition, are generally intermixed in their distribution areas and often subject to common conservation measures.

Distribution

These habitats are exclusive to the three main archipelagos of the Macaronesian biogeographical region in the EU: the Azores, Madeira (both in Portugal) and the Canaries (Spain). The Macaronesian laurel forests have been exploited since people arrived in the Canaries around 2500 BP. More intensive use since European colonization in the 15th century has significantly reduced their surface area.



Percentage distribution of the total surface of Macaronesian laurel forests in Natura 2000

Macaronesian laurel forests in Natura 2000 sites

The following data have been extracted from the Natura 2000 Network database, elaborated by the European Commission with data updated on December 2006. The surface was estimated on the basis of the habitat cover indicated for each protected site and should be considered only as indicative of the habitat surface included in Natura 2000.

MACARONESIAN REGION Country - archipelago	Nº of sites	Estimated surface in Natura 2000 (ha)	% of total surface in Natura 2000
Portugal - Azores	7	3,665	16
Portugal - Madeira	1	12,687	55
Spain - Canary Islands	53	6,612	29
TOTAL	61	22,964	100

Main habitat features, ecology and variability

This habitat type is extremely rich in flora and fauna species, many restricted to these communities. The main characteristic plant species are: *Laurus azorica*, *Laurus novocanariensis*, *Myrica faya*, *Ocotea foetens*, *Persea indica*, *Apollonias barbuiana*, *Clethra arborea*, *Erica arborea*, *Erica azorica*, *Ilex canariensis*, *I. perado ssp. azorica*, *I. perado ssp. perado*, *Isoplexis canariensis*, *Ixanthus viscosus*, *Juniperus brevifolia*, *Picconia azorica*, *P. excelsa*, **Pittosporum coriaceum*, *Pleiomeris canariensis*, *Prunus lusitanica*, *Rhamnus glandulosa*, *Sambucus lanceolata*, **S. palmensis*, *Frangula azorica*, *Heberdenia excelsa*, *Visnea mocanera*, etc.

Most of these tree species are ancient endemic species (Paleoendemic species), e.g. species of the genera *Persea*, *Ocotea* and *Picconia*, which in ancient times were widely distributed on the continent. Nowadays they are confined to this ecosystem thanks to the stable and moderate climate of these oceanic islands, and have not evolved significantly since their arrival (Humphries 1979). Nevertheless, most of the endemic species in this habitat, especially those of the herbaceous and shrub layer, appeared through gradual independent speciation from ancient colonizers from the continent (e.g. species of the plant genera *Argyranthemum*, *Pericallis* and *Sonchus*).

Ecological requirements

Macaronesian laurel forests grow in deep soils at an altitude of 500 to 1,500m in mountain cloud belts (orographic strata) that form under the influence of NE moisture-laden winds in the Canary Islands and Madeira, and SW winds in the Azores. They grow in conditions involving an average annual temperature of 13-19 °C and precipitation between 500 and over 1,500 mm (up to 3,800 mm in the hyper-humid laurisilva of the Azores, according to Dias 2001) and under fog-drip, and are therefore not subject to climatic stress. They are a feature of the parts of the Canaries with the highest net primary production.

Laurel forest tree species can be classified according to their regeneration strategies, i.e. their ability to produce: i) a seed bank - *pioneer species*, such as *Erica*; ii) a seedling bank - *itinerant mature species*, such as *Heberdenia*, *Rhamnus*, *Viburnum* or *Picconia*; iii) a sucker (asexual sprouts from the roots or stem base) bank - *persistent species* such as *Ilex*, *Pleiomeris* and *Prunus*) or various bank types simultaneously; iv) seed and a sucker bank - *persistent pioneer species*, such as *Myrica*, or v) a seedling and a sucker bank - *facultative mature species* such as *Laurus*, *Ocotea*, *Persea* and *Apollonias* (Fernández-Palacios *et al.* 2004). All the tree species producing a sucker bank display 'jail-shaped' multi-stem adult individuals, where the centre of the circle, the former place of the first stem (the original seedling) is empty, and with several concentric generations of suckers, the oldest on the inside and the youngest on the surrounding periphery.

Subtypes identified

Depending on the conditions of water availability, laurel forests can be classified into the following subtypes (Santos 1990): *dry laurisilva*, with precipitation <500 mm and higher temperatures, located on southern slopes, only occasionally exposed to the influence of the cloud belt; *humid laurisilva*, located on the windward slopes under the influence of the cloud belt, with lower solar radiation resulting in lower temperature and precipitation between 500 and 1,200 mm (not taking into account horizontal precipitation); a third type is the *hyper-humid laurisilva* with precipitation over 1,500 mm, only found on Madeira and the Azores. A humidity gradient shows humidity declining from north to south, making Madeira's laurel forests more similar to those of the Canary islands but very different to those of the Azores.

Laurel forest can be classified by characteristic features and species composition into three sub-types, one on each Macaronesian archipelago. Their conservation statuses are also different:

- Lauriphyllous forests of the Azores (45.61 *Ericetalia azorica* p.), with a structure and floral composition different from the Madeira and Canary types, including two sub-types: the humid forests of the coastal areas (*Myrico-Pittosporietum undulati* p.), which have been almost totally degraded or largely invaded by the introduced Australian tree *Pittosporum undulatum*, and the hyper-humid forests (*Culcito-Juniperion brevifoliae* p.) at higher elevations, where better examples survive.

- Lauriphyllous forests of Madeira (45.62 *Pruno-Lauretalia azorica*) still occupy a relatively large surface area of around 13,500 ha. Unlike in the Azores, the topography of the Madeira archipelago is precipitous and rugged. The highest peak rises steeply to 1,861 m. As a result, half the slopes have a gradient of 25% or more. This abrupt landscape has a strong influence on local climate, making the north-facing slopes much wetter than southern slopes. The mountain tops are regularly shrouded in cloud.

- Lauriphyllous forests of the Canaries (45.63 *Ixantho-Laurion azoricae*); each island's laurel forests harbour a distinctive set of endemic plants and animals. In the Canaries, the weather is generally much warmer and drier. The more westerly islands have more dramatic topography, including high mountain peaks that encourage cloud belt formation.

A typical feature of the islands' flora is the high proportion of rare and threatened species with a naturally small range and population size, factors that make them more vulnerable to a variety of threats. This feature can also be seen in Macaronesian laurel forests, which harbour a high number of threatened species. Over 160 threatened species have been recorded in Canary Island laurel forests, accounting for more than 40% of the threatened flora on the archipelago (Fernández & Marrero unpublished).

Despite their northerly distribution (28-40° North latitude), these forests have some features typical of tropical vegetation. They are evergreen forests growing in areas not subject to frost and where constant humidity is guaranteed by a cloud belt that forms under the oceanic influence. Their biomass amounts to 300 tons/ha and their canopies can grow to over 30 m. They may contain up to 20 different tree species in a few hectares (Santos 1990), quite high figures for temperate forests. In addition, fruits are available to frugivorous birds all year round for various reasons: i) the influence of altitude on the ripening process, fruits at low elevation ripening while those higher altitudes are still unripe (Naranjo pers. comm.); ii) the synchronization in fruit production throughout the year peaks among different tree species and individuals within the same species, and iii) as the most important tree species (*Laurus*, *Ilex*, *Myrica*, *Picconia*, *Persea*) present an almost continuously, non-seasonally controlled fruit production pattern, with peaks and troughs that usually vary from one year to another (Arévalo *et al.* 2007, MMAMRM in prep.).

Species that depend on the habitat

Some endemic bird species or subspecies live almost exclusively in the laurel forests, e.g. the three endemic pigeons *Columba bollii*, *C. junionae* and *C. trocaz*, as well as the Azores bullfinch *Pyrrhula murina*. Others, such as the blue chaffinch *F. teydea*, also occur in this habitat type, but infrequently.

The Madeira laurel pigeon *Columba trocaz* is an endemic bird of Madeira. In the early days of human colonisation of the island it occurred in large numbers, but due to very heavy persecution and dramatic loss of habitat (85%), it is now a threatened species. The remaining 15% of laurel forest (about 15,000 ha) is now under the jurisdiction of Madeira Natural Park (Oliveira & Heredia 1995), which has been monitoring the population of the Madeira laurel pigeon for the last 20 years. After a downward trend between 1995 (c.10,000 indiv.) and 2003 (c. 5,600 indiv.), the population is now estimated at around 7,000 individuals. The census carried out in 2006 (unpublished data) showed a slight increase in relative densities of *Columba trocaz* populations within the whole study area. This kind of fluctuation among natural populations is explained by stochastic factors not under human control, and confirms that the current monitoring scheme is adequate and essential for the management and conservation of this endemic species. All efforts should therefore be made to maintain the protection level of this species and its habitat.

The dark-tailed laurel pigeon *Columba bollii*, endemic to the Canary Islands, occurs in the laurel forests of Tenerife, La Palma, La Gomera and El Hierro. It was extinct in Gran Canaria by the end of 19th Century. The population has been estimated at 650 pairs (Blanco & González 2006). The species principally inhabits areas where closed-canopy laurel forest is most developed and with the greatest plant diversity. They nest exclusively in trees within the laurel forest, mainly *Erica arborea*, *Laurus azorica*, *Myrica faya* and *Ilex canariensis*. Their diet chiefly consists of fruit (*Laurus*, *Persea*, *Ocotea*, *Ilex*, *Visnea*, *Myrica*, *Rhamnus*, etc; Martín *et al.* 2000). This pigeon's range has contracted substantially since the 19th century (González 1995).

The white-tailed laurel pigeon *Columba junionae* is endemic to the Canary Islands, occurring in laurel forests on Tenerife, La Palma and La Gomera islands. There are estimated to be several thousand individuals (Madroño *et al.* 2004). It prefers mature laurel forests, but also occurs in degraded laurel forest, scrub with *Myrica faya* and *Erica arborea*, generally along the lower edges of major laurel stands in Canary pine forests (*Pinus canariensis*), mixed pine stands, generally found along the upper edges of laurel forest, and cultivated areas. The enormous reduction in laurel forest cover over the last 500 years has resulted in a substantial contraction of the species' range (González 1995b).

The endemic Azores bullfinch (*Pyrrhula murina*) is highly endangered as a result of the extreme reduction in laurel forest in the Azores. Once a common sight, it declined dramatically to less than 100 individuals. After the beginning of a LIFE-Nature project that includes habitat restoration (laurel forest) the population within the few remaining patches of native forests in São Miguel is currently estimated at 400 pairs (SPEA 2006).

Related habitats

Laurisilva is closely related to another habitat typical of the region, i.e. Macaronesian endemic heaths containing *Erica arborea* and *Myrica faya* (code *4050), also included on Annex I of the Habitats Directive as a priority habitat. They are *Ericaceous* formations at low and medium-tall stages¹ and their main characteristic species are: *Adenocarpus foliolosus*, *Calluna vulgaris*, *Chamaecytisus proliferus ssp. proliferus*, *Erica arborea*, *E. maderensis*, *E. platycodon*, *E. platycodon ssp. madericola*, *Ilex canariensis*, *Juniperus brevifolia*, *Juniperus cedrus ssp. maderensis*, *Laurus azorica*, *Myrica faya*, *Pteridium aquilinum*, *Sorbus maderensis*, *Teline canariensis*, *T. splendens*, *T. stenopetala*, *Vaccinium cylindraceum*, etc.

Both communities are associated in a vegetation community known as “monteverde” in the Canary Islands, which is found in the cloud belt areas of these islands. Both habitats are interrelated and often intermixed in natural areas.

As a general trait, the laurel forests are dominated by tree and shrub species with laurel-shaped leaves, while in the Macaronesian heaths ericaceous species predominate. Species composition is also different although the two habitat types also share a number of species that are found in both, e.g. *Erica arborea*, *E. platycodon*, *Ilex canariensis*, *Juniperus brevifolia*, *Laurus azorica*, *L. novocanariensis*, *Myrica faya*, *M. rivas-martinezii*, etc. Laurel forests are generally taller and have more climbing plants, ferns and epiphytic mosses than Macaronesian heaths, where herbs and shrubs that prefer drier sunnier environments are more abundant.

Laurel forests prefer more humid and sheltered settings with greater climatic stability, well-balanced precipitation and mild temperature, while the Macaronesian heaths are more tolerant to drier, more open or exposed areas with stronger climatic variations and higher continentality. The Macaronesian laurel heaths normally appear in the transition zone to laurel formation on the lower and upper limits of the latter. These heaths can also be considered, under certain conditions, as a pioneer formation that can evolve into laurel forest in the course of the natural succession.

Being so closely associated, both habitat types are normally subject to joint management in the areas where they are found. This management model describes management measures for both habitat types.

¹ *Andryalo-Ericetalia: Fayo-Ericion arboreae, Telino-Adenocarpion foliolosae* (Canary Islands); *Polysticho falcinelli-Ericetum arboreae* and *Teucroio francoi-Origanetum virentis* (Madeira); *Calluno-Ulicetalia: Daboecion azoricae, Ericetum azoricae, Daphno-Ericetum azoricae* (Azores).

Ecological services and benefits of the habitat

Laurel forests play a very important role in water catchment and aquifer recharge. These belts of evergreen forest almost permanently shrouded in mist act as sponges that soak up the moisture from the cloud belts, filling the islands' aquifers, rivers and streams. This phenomenon is known as "horizontal precipitation" and provides an additional source of water in these ecosystems. A study conducted in Garajonay National Park on La Gomera island estimated that the fog water trapped by vegetation is approximately 20-45% of rainfall and is distributed throughout the year, being particularly important in the dry summer season (Ritter *et al.* 2005).

A study in Madeira showed that laurel forest may provide an extra input of water to the ecosystem of 22.5%, which has implications for the ecology of this forest by keeping humidity levels high during summer, laurel forest stands permanently lush, as well as maintaining summer flows from spring and water galleries. That study also concluded that fog is an important water resource, and vegetation is a central key in trapping fog water; it also points out that due to the foreseen climatic changes involving a decrease in Madeira's mean annual precipitation, reforestation with native trees is of paramount importance as a way of naturally balancing the island's ground water resources (Prada *et al.* 2007).

Bryophytes also play a key role in cloud sea interception, encouraging the conversion of very small drops into precipitation. Some liverworts of the genera *Frullania*, *Radula* and *Lejeunea* present adaptations to minimize water loss, e.g. their shape or morphological structures that act as water bags. Furthermore, bryophytes play an important role in nutrient cycles and biomass production, being considered good indicators of the ecosystem's conservation status and of the incidence of pollution (Fontinha *et al.* 2006).

These forests also contribute significantly to soil protection and humus formation, preventing erosion on steep mountain slopes.

In addition, they provide shelter for many species, including a large number that are endemic and threatened.

Trends

Thanks to fossil remains from Madeira (Sziemer 2000), Macaronesian laurel forests are known to have been present on these Atlantic islands for at least 2 million years. They are considered a relict of the forests which in the Tertiary (more than 20 million years ago) covered a large area around the former Mediterranean Sea (Tethys), now corresponding to Southern Europe and NW Africa). After a series of geological and climatic changes, including the Quaternary glaciations, they found refuge in the more temperate regions of North Africa and the Macaronesian archipelagos. When the glaciations ended, the deserts extended over North Africa and this habitat type remained only in border areas of the temperate and the tropical zones, i.e. the Macaronesian region (Axelrod 1975, Santos 1990).

The Macaronesian laurel forests have been intensively exploited since Europeans arrived in the 15th century (Parsons 1981). Extensive areas of forest were razed to create farmland, greatly reducing the original forest cover, while forest exploitation and livestock raising have degraded and impoverished the forest in terms of species composition.

In the Azores, the laurisilva has almost completely disappeared. In the 19th century, wood was used for ship repairs and construction, as well as burned for charcoal production. Later, because of the island's relatively gentle relief and rich soils, the land was used extensively for agriculture (first cereals, then sugar cane and later, orange groves) and as pastureland (Dias 2001), undergoing severe deforestation. This makes them ideal for dairy farming; the Azores currently produce 30% of Portugal's dairy products. As a consequence of this and of the large number of introduced exotic species, only 2% of the original laurel forests remain. In the 20th century, many potential laurel forest areas came under intensive production of *Cryptomeria japonica* and, to a lesser degree, *Robinia pseudoacacia*, *Acacia melanoxylon*, *Eucalyptus globulus* and *Pinus pinaster* (Dias *et al.* 2007).

Madeira can only boast well conserved remains of laurel forests on its more inaccessible northern slope at altitudes of between 600 and 1300 m, which may represent about 15% of their original area on this island.

Its over 15,000 ha make it the largest laurisilva forest on the Macaronesian islands. That figure still includes areas of primary forest, considered among the best stands of laurisilva in the Macaronesian region. The level of endemism in plants and animals is reported to be particularly high.

In the Canary islands, the total current distribution area of laurel forest is estimated at 16,500 ha, of which only about 6,000 ha correspond to well conserved forests, mainly on La Gomera island (Garajonay National Park), Tenerife island (on the basalt massifs of Anaga and Teno) and La Palma island (Los Tiles Reserve). This area currently represents around 18% of its potential, distribution area on this archipelago, and the situation varies considerably depending on the islands, with 52% of the potential area being on La Gomera but only 0.5% on Gran Canaria (Fernández 2001).

Table 1. Potential and actual surface area of laurel forests in the Canary islands (Fernández 2001)

CANARY ISLANDS	laurel forest potential surface area (ha)	laurel forest actual surface (ha)	%
LA PALMA	20.000	5.242	26%
EL HIERRO	6.160	2.445	40%
LA GOMERA	8.840	4.602	52%
TENERIFE	38.540	4.027	10%
GRAN CANARIA	19.050	103*	0,5%
TOTAL	92.590	16.419	18%

* Laurel-forest reforestations, which may currently exceed the figure for relict forest on Gran Canaria, are not included (Naranjo pers. comm.).

The main reason for the significant reduction in laurel forest over most of the Canary islands was the felling that took place to make way for mid-altitude farmland to grow potatoes, cereals and fruits. Nevertheless, the transformation of the agrarian economy into a tourism-based economy over the last 50 years led to the abandonment of about 50.000 ha of agricultural land, where secondary succession towards Macaronesian heaths has occurred.

Laurel forests have traditionally been exploited on these islands, chiefly *Erica arborea* and *Myrica faya*, for the production of charcoal and to meet the demand for wooden poles and tool handles used in growing tomatoes, bananas and vines. This traditional exploitation has decreased considerably on all the islands, which has enabled the forest structure and composition to recover, but even today some laurel forests are still exploited, especially on La Palma island.

Moreover, some large areas originally covered in laurel forests were converted into forest plantations of *Pinus radiata* and *Pinus canariensis* in the Canaries, *Cryptomeria japonica* and *Eucalyptus globulus* in the Azores and Madeira. However, some laurel forest species are also recovering in these reforested areas.

The reduction in laurel forest continued until recently. Nevertheless, a significant proportion of the remaining forest is currently protected and has experienced little disturbance in the last 50 years. In the Canary Islands, 85% of the laurel forest is protected within the Canaries' protected areas network ("Red Canaria de Espacios Naturales Protegidos"), whereas up to 92% within the Natura 2000 European network (Naranjo pers. comm.), and about 60% is on public-owned land (Fernández & Marrero unpublished). No data are available about the age of the remaining laurel forests; some parts are assumed to be only a few generations old, whereas for others there are no official exploitation reports for the last three hundred years although illegal disturbance probably occurred until 50 years ago, creating some earlier succession patches.

On Tenerife island, only 10% of the original laurel forest remains and has been formally protected since 1988. It is currently experiencing less disturbance and no reduction in surface area. Aerial photographs from 1952 show the forest to be similar to its current state in terms both of extent and appearance. In the

1940s, some illegal, small-scale forest exploitation was still taking place (Arévalo & Fernández-Palacios 2003).

Most of the remaining laurel forests have suffered alterations, resulting in rejuvenation and thus a reduction in their original diversity and a simplification of their structural and functional features (Fernández 2001). Several laurel forest restoration programmes are currently being implemented (see below) and studies are being conducted to improve knowledge of forest dynamics (Arévalo & Fernández-Palacios 1998, 2000, 2003, 2005, 2007; Arévalo *et al.* 2007; Arteaga *et al.* 2006; Bermúdez *et al.* 2007; Arévalo *et al.* in press).

Current protection of most laurel forests under national laws and Natura 2000 will make it possible to improve them (MMAMRM in prep.). There are good perspectives for the conservation and spontaneous recovery of the remaining laurel forests. Nevertheless, in areas where the habitat was greatly reduced, as on Gran Canaria and the Azores, laurel forest recovery might only be possible through restoration programmes.

Threats

Habitat degradation due to forest exploitation

Clear-cutting of small areas of laurel forest stands has been the dominant silvicultural technique on Macaronesian islands and is still carried out in some areas such as La Palma in the Canaries. Historically, the main laurel forest products have been: (i) charcoal obtained mainly from *Erica arborea* and *Myrica faya*, (ii) several agricultural tools from stems and (iii) green litter for compost production. In recent years the laurel-forest product most in demand in the Canaries has been green litter for compost production on banana plantations. Traditional management of laurel forest on La Palma has meant harvesting with intervals of 8-10 years, and recent studies have shown that this does not allow the full structural recovery of the stand (Bermúdez *et al.* 2007).

As a consequence of numerous repeated clear cuttings, which encourage vegetative regeneration, low and very dense formations often appear. They mainly consist of the most pioneer and light-tolerant species, which create an impenetrable mass of vegetation that prevents the growth of certain species due to strong competition. Some late successional plant species may become locally extinct if cutting is very frequent. In some areas, selective cutting of the most commercial species resulted in a modification of the original forest structure and composition. Fortunately, this kind of forest exploitation has almost disappeared, and in the Canaries it is now restricted to La Palma.

Habitat transformation and degradation due to livestock farming

Conversion into cattle pasturage has eliminated most laurel forest in the Azores archipelago. Furthermore, cattle have also degraded the habitat in some areas, preventing the regeneration of certain species which were restricted to the most inaccessible sites. Although the impacts of forest exploitation and cattle farming have been significantly reduced, they have not been eliminated completely in some areas.

The Azores islands suffer from heavy eutrophication due to the large numbers of dairy cattle. Livestock grazing in general is a problem for the island's vegetation as indigenous plants have not had time to evolve appropriate defence mechanisms against such pressures. As a result, even 'normal' grazing levels can have a very negative impact on the survival rates of many endemic plants and animals.

Habitat fragmentation

Habitat reduction normally results in fragmentation, which has important consequences at two levels: endangered habitat diversity (at genetic and landscape levels) and extinction of species belonging to laurel forest micro-habitats owing to the isolation of populations. Different situations occur depending on the island. On La Gomera, for example, laurel forests are found at a single compact site. On La Palma, there are two large separate sites, as well as a significant number of small distant sites that are highly

degraded. On Tenerife, two well conserved sites are found at the extremes of their original area (Anaga and Teno), with an important but heavily degraded and isolated site in the centre of the potential distribution area. The worst situation occurs on Gran Canaria, where laurel forest surfaces are scattered over several highly degraded patches covering a total surface area of about 100 ha, not including laurel-forest plantations.

In the Azores, where laurel habitat once covered the islands from sea level to the mountain peaks, the situation is dramatic: several laurel habitat sub-types have become extinct and most are either very degraded or receding.

Another important consequence of habitat fragmentation is the role of paved and unpaved roads across laurel forest remnants as dispersal corridors that permit exotic plant and animal species to reach otherwise remote and undisturbed areas.

The fact that this habitat is restricted to islands brings additional problems involving the biological mechanisms affected by the insularity process.

Invasive alien species

The invasion of laurel forest habitats by exotic species is a major concern especially in the Azores and Madeira, where they had a severe impact. In particular, *Pittosporum undulatum*, an evergreen tree native to south-eastern Australia and often used as an ornamental plant because of its attractive fragrant flowers, has invaded laurel forest in the Azores. *Hedychium gardnerianum*, native to the Himalayas, was introduced as an ornamental plant in Madeira, where it became a serious problem, invading large tracts of laurel forest inside Madeira Natural Park. A more recent problem has been the explosive naturalization of *Clethra arborea*, a tree endemic to Madeira and cultivated as an ornamental species, in the best remnants of São Miguel (Azores) laurel forest.

Due to the urgent need to control exotic species in Madeira's laurel forest, in 2005 Madeira Natural Park developed a program for the control and eradication of alien species, which includes mapping invasive species that threaten the native flora, e.g. *Acer pseudoplatanus*, *Agapanthus praecox*, *Ailanthus altissima*, *Arundo donax*, *Fuchsia magellanica*, *Hedychium gardnerianum*, *Hydrangea macrophylla*, *Passiflora mollissima*, *Pittosporum undulatum* and *Solanum mauritanium*. Although *Hydrangea macrophylla* and *Agapanthus praecox* are relatively frequent in the laurel forest areas, they are not problematic, both being used as ornamental plants along the margins of paths and "levadas" (water courses and canals traditionally use for irrigation) as they have been seen to be unable to invade mature forests.

By contrast, it is surprising that no exotic tree species has yet been reported as having seriously invaded laurel forest stands in the Canaries although some alien species, such as *Ageratina adenophora*, *Tradescantia fluminense*, *Crassula multicava*, *Ailanthus altissima*, *Acacia sp. etc.*, are considered potentially invasive plants that should be eradicated or controlled in laurel forest (MMAMRM, in prep.).

Exotic animal species, such as the rat (*Rattus rattus*), are also considered a threat to laurel forest, as they predate nests of laurel pigeons, etc., and could alter forest dynamics and regeneration as they feed on fruits and may also cause defoliation. Seed predation by rats could have an important effect on some laurel forest species recruitment, as it has been shown for *Ilex canariensis* (Salvande et al. 2006).

Forest fires

Forest fires are considered an important threat, especially in some laurel forests in the Canaries. For instance, in Garajonay National Park on La Gomera, which harbours very well conserved laurel forests, forest fires are considered a serious threat, bearing in mind their very negative potential impact on these forests. In general, old trees have low resistance to fire owing to their limited vitality, the numerous hollows, abundant deadwood and fallen leaves around them, which can prolong the duration of a fire, causing the death of the tree. Although many of the typical laurel forest species are not very flammable, most of them have thin bark that does not protect them against the heat. As a consequence, the fire could destroy the forest and cause irreversible losses, bearing in mind the time needed for recovery. Moreover, the pioneer vegetation that would colonise the site after a fire is more combustible and

therefore could increase the risk of new fires. Thus, the destruction of old and not very flammable forests may imply an increase in forest fire risk. Nevertheless, fires are much more common in Canary Island pine forests or degraded *Erica* heaths than in well preserved laurel forest, mainly due to the high moisture level all year round.

Climate change effects

Laurel forest habitat very much depends on particular climatic and orographic conditions. A recent study on climate change in the region of the Canary Islands and the potential implications for the laurel forests of Tenerife has been carried out (Sperling *et al.* 2004). Frequent orographic cloud formation during the dry season is of vital importance to the altitudinal distribution of the laurel forests because it maintains a semi-humid environment in the otherwise semi-arid Mediterranean-type climate of the Canary Islands. The distinctive environmental conditions in conjunction with the location of the Canary Islands on the northern poleward edge of the Hadley Circulation make these ecosystems potentially highly sensitive to regional changes in climatic conditions.

The study reports a significant increase in relative humidity and a decrease in diurnal temperature ranges in Tenerife at altitudes below the trade wind inversion within the last 30 years during the dry season, which suggests an increased occurrence of low-level clouds. There is also partial evidence for a drying trend across the trade wind inversion, which may be linked to increased subsidence. Overall, the model suggests a downward shift in the area climatically suitable for laurel forests, which may be driven by changes in temperature and moisture supply in the region as well as by larger-scale changes in the atmospheric circulation. This downward shift can threaten this forest because the altitudes immediately below the present cloud belt influence areas are largely covered in arable fields (potatoes, cereals, vineyards, etc.) and housing developments. These findings contrast with previously published findings for a tropical mountain cloud region, which predict an upward shift of the cloud base. This suggests that the ecological consequences of climate change for cloud forests may be linked to their relative location in the Hadley Circulation.



Also taking into account the temperature increase predicted for these islands, a reduction in the potential area of laurel forests could be expected.

An indirect consequence of climate change on the laurel forest in particular and on all the Macaronesian ecosystems in general is the incidence of very infrequent, if not totally unknown, meteorological climatic events now triggered by climate change. One such case was the Delta tropical storm that hit the Canaries and Madeira on 28 and 29 November 2005, with winds reaching 250 km/h. This tropical storm had a severe impact on the laurel forest, especially in forming new canopy gaps, which significantly increased gap size expected under normal climate forest dynamics, and in turn may have repercussions on future forest canopy structure (Arévalo & Fernández-Palacios 1998).

Huge canopy gap in the laurel forest of Anaga (Tenerife) produced by Delta tropical storm in November 2005 (Photo: Manuel Arteaga).

2 Conservation management

General recommendations

The reduction in Macaronesian laurel forest has been so dramatic that at present this habitat barely represents 10% of its original total surface in the region, and thus requires considerable efforts to improve its current status and to prevent further degradation.

A significant proportion of the remaining laurel forests is currently protected and has experienced little disturbance in the last 50 years. As a general rule, mature, well developed laurel forests in good ecological condition should not be subject to active management. Instead, they are left to evolve as naturally as possible, with follow-up in most cases (monitoring indicators described below).

Nevertheless, many laurel forest areas are highly degraded or in a secondary succession stage, mostly due to past use, which justifies the need of active management oriented to promoting their recovery and improving their status. The recent abandonment of some agricultural land has allowed the recovery of some areas currently at a secondary succession stage. Proper management of these areas to boost habitat recovery represents an opportunity to reduce laurel forest fragmentation.

The type of management should be chosen according to the degree of habitat evolution. A recent study in the Canary Islands (Serrada *et al.* 2005) has drawn up a classification of Macaronesian heaths and laurel forests, proposing different types of management in relation to their status (see below: active management).

The Macaronesian endemic heaths can be seen, in many cases, as succession phases towards evolution into laurel forest habitats. In some cases this occurs naturally (as in recent volcanic soils where they have not had time to evolve into a more complex community although the potential conditions exist), while in others it came about artificially due to intervention in laurel forest habitats via tree felling, fire, etc. The complex decision whether the Macaronesian endemic heaths habitat should be managed to maintain the characteristics of this habitat or to evolve towards a laurel forest habitat has to be taken on a case-by-case basis, taking into account local conditions.

In some old forest plantations, in areas formerly occupied by Macaronesian laurel forests and heaths, spontaneous recovery of these habitats is occurring, offering good opportunities for action to boost the process. It is important to avoid clear cuts and carry out successive gradual clearings in order to prevent excessive light exposure to allow the recovery and recolonization of laurel forest species (Fernández 2001, Arévalo & Fernández-Palacios 2005).

Differences between regeneration strategies and spatial distribution of species should always be considered in laurel forest management and recovery programs (Arévalo *et al.* 1999, Arévalo & Fernández-Palacios 2003). As regards laurel forest dynamics, recent studies have identified different successional patterns and regeneration strategies with respect to seed bank, sexual and/or asexual reproduction for the most characteristic tree species. Sexual regeneration after clear cuts is only possible for pioneer species with seed banks where germination is prevented in close canopies but common on logged areas due to the heliophylic character of their seedlings. This is the case of *Erica*, and to some extent of *Myrica* as well, which present seedlings until the canopy is too closed (>3 years after harvesting) for them to receive enough light on the forest floor. Subsequently, only seeds of mature species, such as *Laurus*, can germinate under a closed canopy (Fernández-Palacios *et al.* 2004, Bermúdez *et al.* 2007).

In addition to the management of the existing laurel forest, which is the main focus of this document, it is important to stress the need for an integrated conservation approach. It should focus on the global conservation of the laurel forest habitat, taking into account not just what still exists and is mostly included in Natura 2000, but also the areas that are very degraded or even lost but still possible to restore and which constitute key sites to link isolated nuclei or to recover subtypes that have been nearly lost.

In order to understand the dynamics of laurel forest more completely, long-term studies with representative permanent plots are necessary. Other measures that are also important for maintaining

the habitat but not considered as active recurring management are described below under “Other Relevant Measures”.

Active management

Selective cuttings to improve regeneration on stands once heavily exploited

Selective cuttings can be carried out to speed up the recovery of Macaronesian heaths and laurel forests in regenerating stands. The characteristic species of Macaronesian laurel forests and heaths have the capacity to resprout after harvesting, producing vigorous shoots from stumps. In areas that have been regularly and repeatedly subject to clear cutting for many years and then cutting ceased, natural regeneration gives rise to very high shoot densities. For instance, in some such areas on Tenerife (Canary Islands), regenerating stands may have up to 60.000 shoots/ha growing only to 1.5 m high (in a natural laurel forest, densities range between 2.000 and 3.000 shoots/ha). In such a dense stand, only about 5,000 plants are active. The remaining ones are practically dead, with just a few leaves and no capacity to fructify. Such compact stands are dominated by three species: *Erica arborea*, *Myrica faya* and *Ilex canariensis*, and are unable to evolve unless plant densities decrease.

In these areas, a first selective cut is recommended to reduce plant density from 60.000 to around 20.000 plants/ha, thus allowing the stand to grow up to 4 m high. A second selective cut is made to achieve a maximum density of 7.000 plants/ha. At this stage, other plant species start to grow and the habitat is also colonised by fauna species such as laurel pigeons that were unable to use the previous denser forest. From here onwards, the forest is left to develop naturally (Gil Muñoz pers. comm.). Nevertheless, if the stumps are extenuated, the production of vigorous resprouts is prevented and this technique may not be appropriate for restoration programs, e.g. in some stands in Gran Canaria (Naranjo pers. comm.).

Selective cuttings are also carried out in Macaronesian heaths and regenerating laurel forests in Garajonay National Park, La Gomera in order to eliminate suckers from excessively dense formations. Different techniques have been applied in the last years, which have also been monitored in order to assess their results. All the cut biomass was piled up *in situ* to contribute to the ground formation (Fernández & Gómez unpublished).

For the island of Tenerife, a classification proposal of laurel forests and Macaronesian heaths has been made and measures to improve the status of some of them have been proposed (Serrada *et al.* 2005). This classification is based on species composition, average height, density and present species regeneration strategies (vegetative/seed), and also takes into account the natural local conditions that can determine a low average height of the vegetation owing to climatic, soil or slope limitations (identified as stand conditions). It results in seven different types of stands and for each type defined, a proposal is made whether or not active management should take place to improve them, as well as a suggestion of the kind of measures that should be undertaken to achieve it. This is a theoretical model whose application in the field is still in the early stages in most cases. The seven different types according to the above-mentioned criteria are set out below.

1- *Erica arborea*, *Myrica faya* or *Erica/Myrica* low and high shrub-like stands (low height not determined by stand conditions) with medium to high densities, mostly resulting from vegetative regeneration in areas subject to recent cuts. No intervention until they evolve into higher (arboreal) stands is recommended.

2- *Erica arborea*, *Myrica faya* or *Erica/Myrica* low or high shrub-like and any density, with scant development owing to local natural restrictions that cannot be overcome with any treatment. No intervention is recommended, except regarding forest fire prevention and fighting in perimeter areas.

3- *Erica arborea*, *Myrica faya* or *Erica/Myrica* arboreal stands resulting from seed or vegetative regeneration (in this case with tree trunks with more than 20 cm in diameter) and medium to high densities. This type occurs in areas that underwent long periods without intervention and can be considered a model to achieve from the next type. If local stand conditions allow, selective basal cuttings mainly of *Erica* should be made to reduce fire risk, together with plantation or seeding of broadleaf laurel type species (*Laurus*, *Persea*, *Ocotea*, etc.) to increase diversity.

4- *Erica arborea*, *Myrica faya* or *Erica/Myrica* arboreal stands resulting mainly from vegetative regeneration with medium to high densities. Successive selective cuttings with intervals from 5 to 10 years, primarily targeting *Erica* and *Myrica*, are recommended.

5- Transitional laurel forest stands (more than 20% of *Ilex*, *Viburnum*, *Laurus* and other broad-leaved species) and low or high shrub-like laurel forest stands (not owing to stand conditions), resulting mainly from vegetative regeneration and with medium to high densities. This type occurs in areas subject to relatively recent cuts and no intervention is recommended until they evolve into high density arboreal stands. Nevertheless, this situation is not considered very likely.

6- Transitional laurel forests and arboreal laurel forest stands (> 40% *Ilex*, *Viburnum*, *Laurus* and other broad-leaved species), resulting from seed or vegetative regeneration (in this case with tree trunks with more than 20 cm in diameter), with medium to high densities. These stands occur in areas that went through long periods with no intervention and achieved stability. They can be considered a model to achieve from the next type. No intervention is recommended, not even regarding forest fire prevention as the fire risk is very low.

7- Transitional laurel stands and arboreal laurel forest stands, resulting mainly from vegetative regeneration, with medium to high densities. Same intervention as in type number 4 is recommended.

As regards the successive selective cuttings proposed for stands included in types 4 and 7, some further recommendations are made. Cutting intervals (between 5 and 10 years) must be adapted to conditions in each stand, taking into account the cost/benefit of the intervention. This can be studied at local level through experimental trials. Cuts must be selective and undertaken at the base of the plants in order to remove the worst stems. Special care should be taken not to remove all stems in a stump of laurel or other broad-leaved species. On the other hand, this can be done and is even advisable for *Erica* and *Myrica* at certain sites.

Severity of cutting is a delicate issue as the excessive resprouting that can result from such intervention must be avoided, as must poor results, which would make it necessary to intervene at shorter intervals leading to unnecessary extra costs. In regenerating stands, it is advisable to reduce densities by up to 50-70% through basal cutting. However, intensity can be better adapted after assessment of results obtained through the first interventions. Another issue to be considered is horizontal precipitation, which can be prevented in stands that are too dense or too open.

The slope in the intervention area should always be below 50% to prevent soil erosion and loss of nutrients. Finally, as regards the time necessary to achieve the expected results, if the intervention starts on a stand with 10-20 years old plants with an average diameter of 4-15 cm, after three successive cuttings every ten years, the 40-50 year-old plants should have a diameter of about 20 cm. At this stage, the intervention can be considered complete, once the short-term objectives and stand stability have been attained, natural regeneration would be guaranteed through seed production.

As there is still a demand for firewood and agricultural tools, the above interventions with selective cuttings could be planned and carried out bearing in mind that demand.

Converting forest plantations into laurel forest

On all the three archipelagos with this kind of habitat cover, there are areas of exotic and native tree plantations for timber production created several decades ago in what was originally laurel forest. On Madeira and the Azores, the most common artificial stands are those of *Pseudotsuga menziesii* and, especially, *Cryptomeria japonica*. In the Canary islands, they are of *Pinus canariensis* (a native pine species that has been planted below its natural altitudinal belt) and *Pinus radiata*. Old and cleared stands where laurel forest species grow spontaneously under the canopy often offer good possibilities for laurel forest recovery and expansion (Fernández 2001, Arévalo & Fernández-Palacios 2005).

The method that offers most guarantees from an ecological restoration perspective consists of the gradual extraction of the exotic trees in a series of short harvests that allows the spontaneous progression of the laurel forest by natural regeneration, under the remnant exotic canopy. Plantation of some laurel forest species may be necessary when the understory lacks some components that are considered

important. The key is in directing the exotic canopy to optimal conditions of shadow, allowing for horizontal rain pick-up and diminishing rain interception by the canopy. The process ends with the complete elimination of exotic trees, thus freeing the mass of young laurel forest that has grown in their shade.

The protective role of the planted trees in the development process is essential so clear cutting must be avoided, except in very special cases. In addition to landscape impact and erosion aggravation on steep slopes, clear cutting prevents or impedes the growth of tree species of higher succession stages (e.g. the laurel *Laurus azorica* and *L. novocanariensis*) and the associated plants, since they require some degree of shade. This limits the chances of recovery of sun-loving pioneer species such as *Erica arborea* and *Myrica faya*.

The duration of the process, number of harvests and details of the operations required can vary substantially according to each situation. Some cases are presented below.

1) Conversion of *Pinus radiata* plantations into Laurel Forest in Garajonay National Park, La Gomera, Canary Islands, Spain (Fernández & Gómez, unpublished report)

Laurel habitat restoration in this area presents several physical and environmental constraints: thin soils with low organic matter content, reduced water retention capacity, high insolation and summer temperatures, low environmental humidity and a nearly zero precipitation between May and October. Under these conditions, the selected approach involved managing the density of the exotic plantations to create the microclimatic conditions necessary for restoration of laurel habitat under its canopy. Around 200 hectares of 30-year-old well developed pine groves (300-600 m³/ha) located in former areas of laurel forest and Macaronesian heaths were intervened according to the following scheme.

a) *Pine groves without laurel forest regenerating understory*

There was severe initial cutback, extracting around 70% of the tract, including the dominant trees with more developed canopy. Less intense felling proved inadequate because the native *Erica* and *Myrica* are shade-intolerant pioneer species. Plantations made under the remnant pine canopy then try to imitate what is considered to be the original composition. A second pine extraction, between 30-40% of the remnant tract, is necessary after about 6 years and the pines completely eliminated after another 6-10 years. It is, therefore, a slow process, which only concludes when there is sufficient laurel forest growth..

The main disadvantage of this gradual felling method is the damage inflicted by the felling and extraction operations over the regenerating understory. Adequate planning, limiting the use of heavy machinery to a small number of temporary extraction tracks and managing felling direction can avoid or greatly reduce damage. A gradual approach appears to offer several advantages regarding the clear cut method: higher tree growth after the first 5 years of slower growth rates, once a height of 1-1.50m is reached, and there is no need to remove competing vegetation since it does not affect laurel growth.

Once felled, the pine trunks are cut and stacked, as are the smaller branches and residues, which are later shredded. Although expensive, this action is important to reduce forest fire risk when there is a developed understory. In the absence of understory, the unshredded piles can be left on the ground and may serve as cover for wildlife. The moist environment enhances rapid decomposition and humus formation, which in turn favours the germination of laurel species.

In the case of *Pinus canariensis*, however, the stumps' resprouting capacity requires local treatment with herbicides, which should be done in summer to avoid lixiviation.

A key step in accelerating the restoration process, especially when there are no laurel forest elements in the understory, is the planting of laurel species. The two species selected were *Erica arborea* and *Myrica faya*, obtained from plant nurseries from seed collected at carefully selected sites (direct seeding *in situ* was essayed, but the results were not good). Seeding is done in autumn. Germination starts in March and after 2-3 months the plants are moved to their final containers. The following autumn, plants reach 20-30 cm and are ready to be planted outside after the first rains of the season. Seedlings are planted in 40x40 cm holes dug by hand, a small depression being made in the soil around each one to enhance water accumulation. Planting densities range between 1,200-2,000 seedlings/ha (higher in poorer soils). Irrigation during the first summer is needed for the areas intervened, with poor soils and harsh climate.

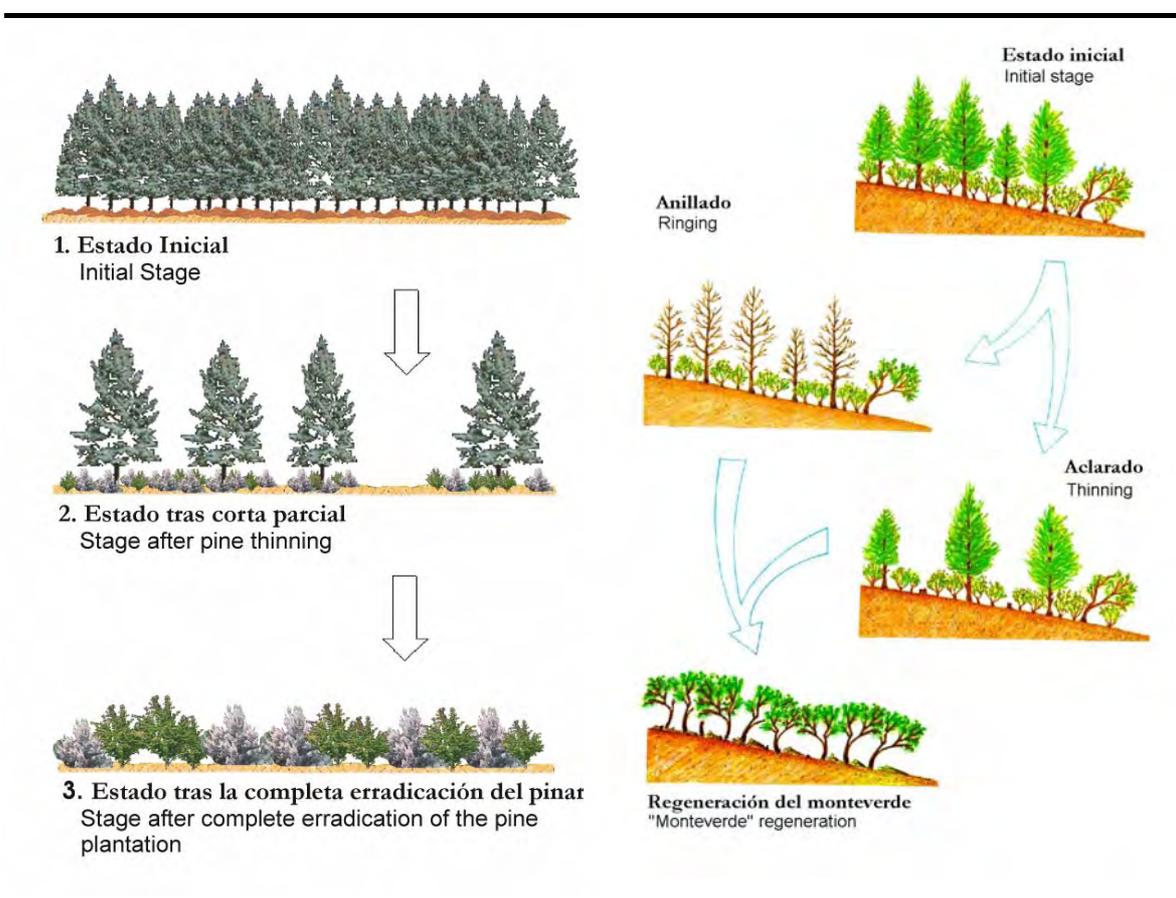
b) Pine groves with laurel forest regenerating understory

The operations required vary according to the state of the understory. In the most favourable cases the pines can be eliminated in a single extraction. Successive clearings are usually needed, the main disadvantage of this method being the damage that can be done to the regenerated vegetation in successive operations. Suitable harvest planning that restricts the use of heavy machinery to temporary forest roads at a suitable distance and also carefully manages fall cutting direction can prevent a lot of damage. Damaged vegetation must be replanted if possible.

In places far away from communication routes, with unsuitable terrain or a well-developed understory that make harvesting operations difficult, partial or complete pine ringing can be done. This consists in extracting the pine bark by making a ring around the trunk, causing the tree to die and gradually decompose. The disadvantages of this method are the loss of timber value, the time needed to achieve the desired effect (around 8 years) and the accumulation of combustible mass. It must therefore be employed carefully in relatively small areas and applying measures to deal with the combustible mass. The advantages are that there is less damage to the native understory, light enters gradually, it is inexpensive and creates optimal conditions for natural recolonization of laurel forest species, avoiding the vigorous regeneration of sun-loving species (*Adenocarpus foliolosus*, *Cistus monspeliensis*) that normally takes place after clear cutting. Such species slow down the later development of typical laurel forest species, and, in the long run, after the laurel canopy finally closes, tend to die, forming a large amount of dead material that enhances the fire risk.

A key question in the conversion of extensive tracts of pine is the spatial arrangement of the operations. Areas with laurel forest understory must be given priority in order to accelerate the formation of interconnected corridors that act as centres of natural regeneration.

Figure 1: Conversion of *Pinus radiata* plantations into Laurel Forest (Fernández & Gómez unpublished report)



2) Conversion of *Eucalyptus globulus* plantations into laurel forest in Anaga (Tenerife, Canary Islands, Spain) (After Hernández-Rodríguez & González-Delgado unpublished report).

The Jardina locality in Anaga Rural Park (Tenerife) was intensively planted in the 1930s for reforestation and timber production purposes using the widespread exotic tree Tasmanian blue gum (*Eucalyptus globulus*). After the Anaga massif was declared a protected area in 1984, the park authorities decided to remove the *Eucalyptus* plantations to enable the native laurel forest to recover. A pilot restoration project in 2005 involved 1.6 ha (800 m asl facing south stand) of 10-15 m tall *Eucalyptus* coppices with 4-12 shoots per crown, with *Erica*, *Laurus* (the single laurel-forest species that seems to survive under a *Eucalyptus* canopy) and several endemic (*Artemisia*, *Aeonium*, *Kleinia*) and exotic (*Opuntia*, *Agave*) bushes forming the understory. The area was subject to a reiterative clear cut until the extenuation and death of the root-crown, which happens after 4-5 resprouting cycles. This environmentally friendly technique avoids the use of herbicides.

After the clear cutting, the logs were removed and 4,000 saplings of several laurel forest tree species present in the area (*Myrica*, *Apollonias*, *Picconia*, *Prunus*, *Ilex*, *Rhamnus*, *Visnea* and *Pleiomeris*, of which *Myrica* accounts for two thirds of the saplings) were planted in autumn (coinciding with the rainy season) in 40cm-diameter x 40cm-deep cylindrical holes 2 m apart. *Erica* and *Laurus*, already present in the understory, formed the basis of the restoration, together with *Myrica*. The latter is a very special component of laurisilva due to its pioneer-persistent strategy and especially owing to its capacity to fix atmospheric nitrogen in symbiosis with *Franckia* bacteria, which results in high colonization and edaphogenetic capabilities. *Myrica* deserves a central role in laurel-forest restoration programmes.

3) Conversion of degraded areas into laurel Forest in Los Tilos de Moya Special Natural Reserve, Gran Canaria, (Canary Islands, Spain)

Los Tilos de Moya Special Natural Reserve is witnessing the restoration of several degraded laurel forest areas, some of which include forest plantations of *Eucalyptus* sp. and/or *Castanea sativa*. The intervention area was zoned according to the characteristics of the vegetation cover in each plot.

Substantially degraded areas, with just a few individuals of characteristic laurel forest species were subject to alternate vegetation cuts along horizontal stripes, the clearings then being subject to manual planting of a mixture of laurel species selected according to the soil-climatic characteristics of each plot.

Less degraded areas were managed in order to facilitate the development of existing scattered samples of laurel species towards an ecologically more mature state. This was done by planting a mixture of laurel species in clusters comprising 5-10 individual plants of each species in order to avoid competition between species, either using existing vegetation clearings or opening them through vegetation cuttings. The number of plants planted varies from 700 to 1,000 per ha. depending on local conditions.

4) Conversion of *Cryptomeria japonica* plantations into laurel forest in Serra da Tronqueira (São Miguel, Azores)

In the framework of the Priolo LIFE Project (LIFE03NAT/P/000013, see below), a pilot experiment to restore 10 ha of a 30-year-old *Cryptomeria japonica* plantation in Serra da Tronqueira, São Miguel (Azores), into laurel forest was recently attempted. The plantation has been clear-cut, removing the timber for local consumption or export, planting in its place more than 10 native laurel forest tree species (*Erica azorica*, *Myrica faya*, *Laurus azorica*, *Picconia azorica*, *Frangula azorica*, *Ilex perado*, *Prunus lusitanica*, *Juniperus brevifolia*, etc.). As this is a recent intervention, little information on its success is available.

Eradication and control of exotic invasive species

Exotic invasive species are an important problem on Madeira and in the Azores, where significant efforts have been made to address their eradication and control. On Madeira alone, 448 sites containing invasive species have been mapped, 362 of which are located inside the main laurel forest distribution area. All the invasive species inventoried, except *Ailanthus altissima*, are present within the laurel forest habitats. The

most common species is *Hydrangea macrophylla*, present at 21% of the sites, although it does not represent a particularly serious threat since it is mainly located along roads and trails, where it was planted in the past for ornamental purposes. The same is true of *Agapanthus praecox*, present at 13% of the sites. The major problem concerns species such as *Solanum mauritianum* (16% of sites), *Passiflora mollissima* (14%), *Acer pseudoplatanus* (13%), *Hedychium gardnerianum* (9%) and *Pittosporum undulatum* (5%), which despite occupying border areas, show a steady and gradual trend towards laurel forest habitats. The problem is not so great in the Canary islands, but some exotic species are also subject to regular control there.

Some examples of techniques and means are set out below.

Eradication of *Hedychium gardnerianum* -ginger lily- in Madeira (Portugal)

"Garden escapes" are a major threat to laurel forests in Madeira. First introduced in 1934, this Himalayan species underwent a phase of rapid colonisation and became widespread, starting to invade the laurel forests, where it not only smothers other native plants, but also prevents the forest from regenerating naturally. From 1998 to 2000, Life-Nature funding was provided for Madeira Natural Park to recover the habitats of pSCI *Laurissilva da Madeira*, the edges of which were being invaded by *Hedychium gardnerianum* (LIFE97NAT/P/004082).

Eradication is very labour intensive work. *Hedychium* spreads like a thick blanket across the forest floor, from where new plants continually grow. The entire plant structure needs to be removed in order to prevent resprouting. After analysing several strategies, it was found that removal by hand was more efficient because it is more accurate as even small (1 cm³) pieces of rhizome left behind can give rise to a new plant within a few months. The task is made no easier by the difficult terrain.

Madeira National Park cleared a sufficient area to act as a 'cordon sanitaire', ranging from 20 to 500 m large (depending on the threat inherent to each specific situation), preventing further invasion into the forests. Now the situation needs to be closely monitored and any new *Hedychium* re-sprouts promptly removed. Such monitoring is ongoing thanks to the creation of an "exotics prevention brigade" within the Natural Park. Additionally, through an agreement with the army, twice a week a group of 10 soldiers is assigned to help with fieldwork. This co-operation will last as long as necessary. Furthermore, the Natural Park encouraged farmers owning plots of land near the sanitary belt to cultivate them. At first the Park removed exotics, and farmers ensured ongoing prevention of re-sprouting in order to keep their plots cultivated and produce compost (the beneficiary has been providing the farmers with relatively good quality compost made of chopped *H. gardnerianum*; farmers have also started to make it themselves. There is no danger of encouraging the cultivation of exotics for this purpose, as (unfortunately) there are already too many available.

Eradication of *Hedychium gardnerianum* -ginger lily- in S. Miguel (Azores, Portugal)

The eradication of this invasive plant is being undertaken in key areas of the SPA Pico da Vara / Ribeira do Guilherme as part of a restoration programme for the Azores bullfinch (see "Special Requirements Driven by Relevant Species" below).

Ginger lily eradication is being undertaken using both manual and chemical methods. In the second case, several herbicides and concentrations were studied and it was found that metsulfuron methyl (commercially known as Ally), a chemical with very low toxicity in mammals, birds and aquatic organisms, was the most effective, used as granules of 20% metsulfuron methyl in a solution of 6g/l, plus 1ml/l of Trend (solvent) and 0.5g/l of red food pigment (to make the herbicide solution visible once applied). The plants are cut (either manually or mechanically) approximately 10 cm above the rhizome, after which three different techniques are used to assess which is most effective:

- Ally application with sprayer over the cut, avoiding leakage. Plant material resulting from the cut is used to cover the cut to reduce lixiviation;
- the plant is left to grow after the cut until it has 4 to 5 leaves and then it is sprayed with Ally over leaves and rhizome;
- plant is sprayed with Ally immediately after cut, over cut, stem and rhizomes.

The eradication work always progresses from higher to lower altitudes to combat the invasive species' natural colonisation trend.

Eradication of *Pittosporum undulatum* and *Clethra arborea* in S. Miguel (Azores, Portugal)

Pittosporum undulatum (Sweet Pittosporum) from eastern Australia is an invasive plant that was introduced in the Azores as an ornamental. *Clethra arborea*, although native to Madeira and part of the laurel forest flora there, was introduced in the Azores, where in many parts it became the second most aggressive invasive plant after the ginger lily. Both plants are removed by chemical means using the same products and concentrations described above for *H. gardnerianum*. Application technique depends on plant size:

- seedlings are sprayed on the leaves, manually removed, stacked and sprayed again;
- plants with up to 6cm of basal perimeter are manually cut at half their height and sprayed on the cut;
- trees are subject to basal trunk cuts less than 3 cm distant from each other and at approximately 45° in relation to the trunk axis, deep enough to reach the vascular system. Cuts are sprayed so that the herbicide enters the plant's circulation.

Eradication of *Tradescantia fluminensis* -wandering Jew- on La Gomera (Spain)

This exotic herb from South America has spread to some areas of Garajonay National Park. Given its high regeneration rate in its vegetative form and perfectly adapted to wet shady environments such as the interior of laurel forest, it has easily spread in this habitat. It is dangerous mainly because its ground biomass prevents laurel forest seeds from germinating. Every year the park authorities rely on volunteers to remove plants by hand and collect them in plastics bags in order to aid decomposition.

Plant cuttings cannot be dumped anywhere as this is a frequent source of new weed infestations. The origin of new top soil or fill should be checked as physical transportation of plant segments in soil is a major method of spread.

Recovery of threatened species

Some species present in laurel forest are in a critical situation as regards population numbers and conservation status and thus may require special efforts to recover, normally involving cultivation and reintroduction into the wild in suitable areas. Some lessons can be learned from the various measures undertaken to recover endangered laurel forest species.

The effective recovery of an endangered species normally requires a Recovery Plan that defines the measures needed to eliminate the danger, including the necessary studies to orientate the actions and guarantee their feasibility and efficacy. Studies of genetic variability, characterization of the potential habitat to identify ecological requirements of the species in question, reproductive biology (seed viability, latency, pollination, germination, etc.) and regeneration strategies are also recommended. It is very important to consider intra-specific variability in the species to be planted, which requires control of seed origin.

Table 2: Azores, Madeira and Canary Island laurel-forest plant taxa threatened with extinction and subject to recovery plans (Sources: Dias et al. 2007, Favila Faria 2006, Rodríguez Luengo et al. 2003).

Azores (cf.)	Madeira	Canaries
<i>Angelica lignescens</i>	<i>Hymenophyllum maderense</i>	<i>Pteris incompleta</i>
<i>Lactuca wastoniana</i>	<i>Polystichum drepanum</i>	<i>Bencomia sphaerocarpa</i>
<i>Ammi trifoliatum</i>	<i>Goodyera macrophylla</i>	<i>Euphorbia mellifera</i>
<i>Chaerofilum azoricum</i>	<i>Normania triphylla</i>	<i>Ilex perado ssp. lopezlilloi</i>
<i>Euphorbia stygiana</i>	<i>Pittosporum coriaceum</i>	<i>Isoplexis chalcantha</i>
<i>Prunus lusitanica ssp. azorica</i>	<i>Teucrium abutiloides</i>	<i>Myrica rivas-martinezii</i>
<i>Rumex azoricus</i>		<i>Normania nava</i>
<i>Taxus baccata</i>		<i>Pericallis appendiculata</i> var. <i>preauxiana</i>
<i>Urtica morifolia</i>		<i>Sambucus palmensis</i>

Other relevant measures

Regulating activities

Exploitation of laurel forests and Macaronesian heaths is generally subject to certain regulations.

As mentioned above, in areas of well developed laurel forest, such as most of the SCI Laurissilva da Madeira and some areas of Garajonay National Park (La Gomera, Spain), non-intervention is considered the best option, management being confined to ensuring habitat maintenance and allowing it to evolve naturally. However, regulating activities inside these areas is an important issue. Recreational activities are normally regulated and controlled in order to avoid impacts to the most sensitive areas. This generally implies channeling visitor access to certain areas provided with suitable facilities. Hunting may be allowed only in certain areas and at specific times of the year, being regulated by site managers. All other activities are subject to authorisation of site management bodies, usually in accordance with management plans.

In the Canary Islands, the forest authorities have gradually been adopting regulations to control the exploitation of these habitats. These regulations are aimed at preventing clear cutting in private forests and reducing or abolishing exploitation of public forests. As a consequence, some positive changes are already being noticed in the structure and composition of the forests, e.g. the recovery and expansion of shade-tolerant species and others that were traditionally exploited in a selective way.

Ex-situ conservation

As this habitat includes numerous seriously threatened species, ex situ conservation is considered necessary. Seed banks and germplasm banks are kept in the Azores, Madeira and the Canaries for a variety of species (mainly non-arboreal) typical of the laurel forest habitat. The *ex situ* conservation of laurel forest tree genetic resources is currently being studied in the Azores as a way of safeguarding rare species such as *Prunus lusitanica*.

Unfortunately, most laurel forest tree species seeds cannot be kept in germoplasm banks due to their recalcitrant character, i.e. the seeds either germinate or die, a feature typical of most tropical forest tree species seeds.

Monitoring

The development of both well conserved laurel forest habitat and regenerating stands is monitored. The most important monitoring indicators are the characteristic species composition of the different subtypes of laurel forest, average canopy height, tract density and relative importance of regeneration strategies (sexual/vegetative). Other relevant indicators are: accumulated biomass, volume of deadwood and heterogeneity caused by tree-fall gaps.

The use of indicators to estimate the quality of the habitat requires some reference values that should be obtained from the best conserved laurel forest areas for each parameter considered. These areas are currently found in Garajonay National Park (Fernández 2001, Fernández & Moreno 2004), the Reserve of El Pijaral (Anaga, Tenerife), and the Tiles Reserve (La Palma) in the Canary islands, and in Madeira Natural Park (Costa Neves 1996).

On Madeira, monitoring covers evaluation of the maturity and degree of development of laurel forest habitat and close follow up of exotic vegetation sites inside and around the forest, with classification and mapping according to potential risk and intervention priority needs. A potential vegetation map was also created as a reference for future follow up.

In Garajonay National Park, monitoring is being carried out through permanent plots that have been studied over the last 10 years, where flora inventories are being carried out considering the following parameters: species composition, basic population parameters (richness, abundance density), diametric

distribution of the different individuals, spatial distribution, asexual reproduction, existent communities and ecosystems structure.

In Anaga Rural Park (Tenerife), the Island Ecology Research Group of La Laguna University has monitored permanent plots over the last ten years, analyzing parameters such as canopy species composition, diametric distribution, species richness, seedling-adult spatial distribution patterns, sexual and asexual regeneration and fruit production.

In La Palma (Canaries), a post-clearcut chronosequence has been monitored for the last 60 years to determine the recovery of the stands in terms of species composition and diversity, life strategies and structural parameters of the canopy (Bermúdez *et al.* 2007).

Special requirements driven by relevant species

Rat control

Rats have been considered a potential problem in laurel forest regarding the regeneration of characteristic plant species and predation on bird nests, in particular those of endemic laurel pigeons.

A study of the breeding success of laurel pigeons in the Canaries in 1995 revealed significant predation of *Columba junoniae* nests by rats. Effective control of rats may therefore be important locally, in laurel forest with potentially large numbers of rats. Although some nest predation was also detected for *Columba bolli*, it appeared not to be as problematic as for *Columba junoniae*.

Experimental rat control at one of the main pigeon sites on Tenerife, Tigaiga, and monitoring its effects on rats, pigeons and wildlife were carried out as part of a LIFE-Nature project (LIFE96NAT/E/003095). The poison used was brodifacoum 0.005%, administered in blocks with paraffin to protect it from adverse weather conditions. Security bait-boxes were used to avoid its consumption by other species. Two plots were placed in Tigaiga (N Tenerife): one as a control plot (no intervention) and another one to be cleared of rats (43 ha). Bimonthly monitoring of rats, pigeons and other wildlife started in 01/1998. 299 bait-boxes with poison were located (arranged in a network) in the plot to be cleared of rats in 09/1998. Poisoning was repeated, coinciding with the rats' breeding periods. The effects of poison on pigeons (breeding success and population evolution), rats and other wildlife were permanently assessed from then on. The main results and conclusions were:

- Rats were completely eliminated from the plot in four months. Consumption of baits declined constantly and from 01/1999 onwards, it reached a steady near-zero level.
- Pigeon breeding success did not improve despite rat eradication.
- Other factors potentially affecting pigeon breeding rate, e.g. predators (*Accipiter nisus*, *Asio otus*), adverse weather (wind), egg failure, egg infertility and the presence of the work team, should be considered.
- No negative effect of poison on pigeons, other birdlife or vertebrates (carcasses) was detected during the intensive monitoring. However, the invertebrate community could have been damaged.
- Management recommendations to improve the status of pigeons (especially *C. junoniae*) include: avoiding disturbance caused by people in breeding areas, more surveillance to prevent poaching, further monitoring and research, long-term predator-control campaigns.

Assessment of the damage caused by black rats to Madeira laurisilva was undertaken through (a) a study of rat behaviour and habitat use to assess the damage caused to shoots, berries and seeds and (b) a study of the impact on the reproductive success of *Columba trocaz*. Results suggest the impact of rats on the regeneration of laurel forest habitat species is minimal and the global predation rate on pigeon nests is around 27.5%. Although considerable, this is not considered to be of concern, the conclusion being that a rat control or eradication programme is not needed.

Studies of the effect of rats on regeneration of laurel forest species undertaken in the Canary Islands (e.g. in Garajonay) showed no significant negative effect on regeneration.

Recovery of Azores bullfinch (*Pyrrhula murina*) habitat

A LIFE-Nature project was funded between October 2003 and October 2008 (LIFE03NAT/P/000013) with the main objective of recovering the habitat of the Azores Bullfinch a species endemic to the island of São Miguel and largely confined to native vegetation, which is its main food source. This is being achieved, among other measures, through the control of exotic flora and by promoting regeneration of the laurel forest habitat (two of the conservation priorities defined by the Azores Bullfinch Action Plan) inside the Azores bullfinch distribution area by means of:

- a) Chemical and manual removal of the invasive alien species present - *Hedychium gardnerianum*, *Clethra arborea*, *Pittosporum undulatum* and *Gunnera tinctoria* on around 300 hectares.
- b) Annual collection of more than 200 kg of seeds of *Erica azorica*, *Frangula azorica*, *Laurus azorica*, *Picconia azorica*, *Ilex perado ssp. azorica*, *Vaccinium cylindraceum* and *Viburnum tinus ssp. subcordatum*
- c) Propagation of endemic flora specimens in nurseries to restore degraded and deforested areas (more than 50,000 specimens of *Erica azorica*, *Vaccinium cylindraceum*, *Juniperus brevifolia*, *Viburnum tinus ssp. subcordatum*, *Ilex perado ssp. azorica*, *Frangula azorica*, *Prunus lusitanica ssp. azorica* and *Picconia azorica*)
- d) Planting of endemic flora on around 300 hectares within the SPA
- e) Removal of an artificial forest production area of *Cryptomeria japonica* of around 10 hectares, followed by the planting of endemic species.

In this case, the recovery of laurel forest habitats is mainly oriented to create a suitable habitat for the Azores bullfinch, e.g. species are selected mainly by taking into account the feeding resources necessary to maintain the bullfinch population.

Cost estimates and potential sources of EU financing

Most of the actions for the recovery of laurisilva involve very labour-intensive work. Some of the measures must be implemented regularly over long periods, e.g. at least every year as regards control of exotic species, and every 5-10 years over 15-30 years as regards selective cuttings to improve the recovery of laurel forest and Macaronesian heaths. In addition, access to the areas to be recovered can be difficult. Labour costs can therefore be regarded as an important item when estimating costs in conservation management of laurel forests. Light machinery should be used for the proposed recovery measures (e.g. selective cuttings). Surface area and special local conditions (e.g. accessibility, slope) of the areas to be treated should be taken into consideration when estimating effort and labour costs.

As an example, the eradication of invasive *Clethra arborea* and *Pittosporum undulatum* from 6 ha in Azores required 10 field workers at an average of 8.4 workers/day, for 5 months (working 12 days/month and using an average of 32 litres of herbicide per day).

Most of the proposed management measures could be financed with EU funds devoted to nature conservation, such as **LIFE**, which have often been used for the recovery of laurel forest and laurel habitat species. Other funds, such as **INTERREG**, are potentially useful, and have, in fact, been used in the past to control and eradicate alien species; they are currently in use to recover laurel forests on Gran Canaria island. These funds allow the co-financing of full costs for conservation management actions.

Rural Development Fund (EAFRD) may also offer a good opportunity to support the management of laurel forests through Axis 2 measures targeting the sustainable use of forestry land (Art. 36-b), in particular:

- First afforestation of agricultural land (art 43 of EFRD Regulation – 1698/2005).
 1. Support shall cover only:
 - (a) establishment costs;
 - (b) an annual premium per hectare afforested to contribute to covering maintenance costs for a maximum of five years,
 - (c) an annual premium per hectare to contribute to covering loss of income resulting from afforestation for a maximum of 15 years for farmers or associations thereof who worked the land before its afforestation or for any other natural person or private law body.

2. Support for the afforestation of agricultural land owned by public authorities shall cover only the cost of establishment. If the agricultural land to be afforested is rented by a natural person or private law body, the annual premiums referred to in paragraph 1 may be granted.

3. Support for the afforestation of agricultural land shall not be granted for farmers benefiting from early retirement support.

4. Maximum annual premium to cover loss of income from afforestation laid down in the annex of the Regulation: - for farmers or associations thereof: 700 Euro per hectare; - for any other natural persons or private-law bodies: 150 Euro per hectare.

- Natura 2000 payments (EAFRD art. 46). Annual payments per hectare of forest to private forest owners or associations in order to compensate for costs incurred and income foregone resulting from the restrictions on the use of forests due to the implementation of Directives 79/409/EEC and 92/43/EEC in the area concerned. Minimum and maximum amounts laid down in the regulation: 40-200 Euro/ha.
- Forest-environment payments (EAFRD art. 47) per hectare of forest to cover forest-environmental commitments going beyond the relevant mandatory requirements. These commitments shall be undertaken for a period between five and seven years. Where necessary and justified, a longer period shall be determined for particular types of commitments. The payments shall cover additional costs and income foregone resulting from the commitment made. Minimum and maximum amounts: 40-200 Euro/ha.
- Support for non-productive investments (EAFRD art. 49). investments in forests:
 - (a) linked to the achievement of commitments undertaken pursuant to the measure provided for in Article 36(b)(v) - forest-environment payments, or other environmental objectives;
 - (b) which enhance the public amenity value of forest and wooded land of the area concerned.

Structural Funds, in particular the **European Regional Development Fund (ERDF)** can be used to finance infrastructure to improve access linked to biodiversity and Natura 2000 contributing to sustainable economic development and diversification of rural areas (art. 4-6). They could also be used to set up and maintain infrastructure related to ex-situ conservation and cultivations of plants used for laurel forest recovery (e.g. plant nurseries, etc.).

Concerning potential sources of EU financing, a Guidance Handbook (Torkler 2007) presents the EU funding options for Natura 2000 sites in the period 2007-2013 that are, in principle, available at the national and regional level. Furthermore an IT-tool is available on the EC web site: (http://ec.europa.eu/environment/nature/natura2000/financing/index_en.htm).

Acknowledgements

This document was drafted by Ana Guimarães and Concha Olmeda (ATECMA). We must acknowledge the valuable information and advice provided by site managers and experts that have long experience of working on laurel forest and Macaronesian heath conservation management and study.

We are particularly grateful to Angel Fernández (Garajonay National Park, Spain), José María Fernández-Palacios (Universidad de La Laguna, Spain), Pascual Gil Muñoz (Cabildo Insular de Tenerife, Spain), Jorge Naranjo (Gobierno de Canarias, Spain) and Rafael Serrada (Escuela Superior de Ingenieros de Montes, Madrid, Spain) for their significant contributions relating to management practice in the recovery of these habitats in the Canary Islands, and to Eduardo Dias (University of the Azores, Portugal) and Paulo Oliveira and Suzana Fontinha (Madeira National Park, Portugal) for their advice and provision of information regarding habitat management in the Azores and Madeira, respectively.

We would also like to thank Guilherme Zaniolo, who assisted in gathering and arranging the relevant information to draft this document.

Lesley Ashcroft revised the final draft.

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