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A new approach in the monitoring of the phytosanitary conditions of forests: the case of oak and beech stands in the Sicilian Regional Parks

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Abstract

The objective of this study was to investigate the health conditions of oak and beech stands in the three Regional Parks of Sicily (Etna, Madonie and Nebrodi). A total of 81 sampling areas were investigated, 54 in oak stands and 27 in beech stands. The phytosanitary conditions of each tree within the respective sampling area was expressed with a synthetic index namely phytosanitary class (PC). Oak stands showed severe symptoms of decline, with 85% of the sampling areas including symptomatic trees. In general, beech stands were in better condition, with the exception of Nebrodi Park, where trees showed severe symptoms of decline. On oak trees, infections of fungal pathogens were also observed, including *Biscogniauxia mediterranea*, *Polyporus* sp., *Fistulina hepatica*, *Mycrosphaera alphitoides* and *Armillaria* sp. By contrast, on beech trees *Biscogniauxia nummularia*, *Fomes fomentarius* and *Neonectria radicicola* were recognized. Furthermore, twenty-two permanent sampling areas were delimited with the aim of monitoring regularly the health conditions of forests in these three parks.

Keywords; oak; beech; forest stand; phytosanitary class; Sicily; permanent sampling areas

Riassunto

L'obiettivo del presente studio è stato quello di esaminare lo stato fitosanitario delle quercete e faggete dei tre Parchi Regionali Siciliani (Parco dell'Etna, Parco delle Madonie, Parco dei Nebrodi). Lo studio è stato condotto individuando delle aree di saggio, popolamenti forestali omogenei sotto l'aspetto floristico, ecologico e

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fitosanitario. Complessivamente sono state delimitate 81 aree di saggio, di cui 54 quercete e 27 faggete. La condizione fitosanitaria di ogni essenza arborea all'interno della rispettiva area di saggio è stata espressa con un indice numerico denominato “classe fitosanitaria” (PC). I popolamenti di quercia hanno mostrato un elevato grado di sofferenza, con alberi sintomatici nell’85% delle aree di saggio. I popolamenti di faggio hanno mostrato una situazione di maggiore stabilità, ad eccezione delle faggete del parco dei Nebrodi che apparivano molto degradate. Sul genere *Quercus*, sono stati osservati sintomi di infezioni di patogeni fungini comuni nelle foreste delle aree temperate e Mediterranee, quali *Biscogniauxia mediterranea*, *Polyporus* sp., *Fistulina hepatica*, *Mycrosphaera alphitoides* ed *Armillaria* sp., mentre su faggio sono state osservate infezioni di *Biscogniauxia nummularia*, *Fomes fomentarius* e *Neonectria radicicola*.
Sono state altresì individuate 22 aree che vengono proposte come aree di saggio permanenti dello stato fitosanitario delle foreste nei tre parchi.

Parole chiave: quercete; faggete; popolamenti forestali; classe fitosanitaria; Sicilia; aree di saggio

Introduction

The European forests are susceptible to several abiotic environmental stresses, such as fires, loss and aridity of soil, and air pollution. All these factors could make the plants more susceptible to biological stresses, such as plant pathogens, which greatly contribute to the decline of vegetation (COOKE *et al.*, 2007). In the Mediterranean area, the effects due to the aforementioned biotic and abiotic stresses are worsened by the impact of climatic changes and the resulting desertification processes (AUCLAIR *et al.*, 1992; ROSENZWEIG and TUBIELLO, 1997; CHEDDADI *et al*., 2001; HANSEN *et al*., 2006; HANSON *et al*., 2006).
In Europe, oak and beech are not only the most widespread trees in natural vegetation, but also the most sensitive to the stresses caused by the interactions of biotic and abiotic factors, as demonstrated by the numerous examples of severe decline of *Quercus* spp. and *Fagus* spp. stands reported in literature for central Europe (KANDLER 1992; TOMICZEK, 1993; FÜHRER, 1998; RAGAZZI *et al*., 2002; THOMAS *et al*., 2002; JUNG, 2009) and several Italian regions (CAPRETTI and MUGNAI, 1987; VANNINI, 1987; RAGAZZI *et al*., 1989).
In recent years, the application of a methodical and multidisciplinary approach able to define the causes of the environmental decline and the health conditions of forests has largely increased, making it possible to formalize the more appropriate strategies of local, regional and national management. For example, in Italy, this kind of approach has been successfully applied in the framework of regional projects such as META and MONITO in Tuscany, ECAFO in Lombardy, BAUSINVE in Friuli Venezia Giulia, and FITFOREST in Veneto, as well as in projects managed by the Ministry for Agriculture and Forest, such as CONEFOR and INDEFO.
With reference to the Sicilian context, up to now, the studies carried out on oak and beech forests have mainly focused on the role of phytophagous pests and fungal pathogens in the decline of natural vegetation. These researches have highlighted that xylophagous and defoliator insects represent the mainly phytophagous pests, while among the fungal pathogens attacking woody parts, *Biscogniauxia mediterranea* (De Not.) Kuntze, *B. nummularia* (Bullo.: Fr.) Kuntze, *Cytospora* spp., *Diplodia mutila* (Fr.) Mont., *Discula quercina* (Cooke) Sacc., *Phoma* spp. and *Phomopsis quercina* (Sacc.) Höhn, stand out; moreover, pathogens of roots, such as several species of *Armillaria* genus (GRANATA and WHALLEY, 1994; RAGAZZI *et al.*, 1999; SIDOTI and COLLETTI, 2005; SIDOTI and COLLETTI, 2006; SIDOTI, 2011) have been recognized. However, besides the aforementioned examples, the studies of the health conditions of oak and beech forests in Sicily have followed a non-methodical approach, preventing the definition of a systematic analysis routine based on

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standard evaluation models and parameters, without which the comparison between different areas and/or forest stands is quite complicated.
For this reason, with this research, we intended to go behind the state of the art by studying and defining the health conditions of the oak and beech stands in three Regional Parks of Sicily through the application of a well-established method that employs standardized and reference parameters. Apart from the description of the sanitary setting of the studied forests, the obtained results could represent a really useful support tool in the planning of appropriate management strategies of the studied natural parks.

Materials and methods

Oak and beech forests located in the Nebrodi, Etna, and Madonie Regional Parks were selected for the present study. Beech forests were mainly pure stands. As for the oak ones, they consisted in three different typologies represented by: (i) mesophile oak stands of *Quercus* spp., frequently mixed with ash trees, (ii) pure or mixed stands of turkey oak (*Quercus cerris* L. and *Q. gussonei* (Borzì) Brullo), and (iii) mixed thermophile stands of *Q. ilex* L., and *Q. pubescens* s. l. Wild.
Surveys were performed from 2007 to 2015 by using the form arranged by Veneto Region forestry authorities in the framework of the FITOFOR (Phytosanitary Forest Monitoring) project (http://www.unipd.it/esterni/wwwfitfo/immagini/scheda%20rilievo.pdf). The monitoring activities were carried out in fall and spring, since these seasons are the most sensitive to the biological activity of several plant pathogens.
In detail, data were collected in different circular sampling areas of twenty-five meters in radius, representative of the ecological features and health conditions of the forest stands (Fig. 1). Noteworthy is that the center of the sampling circular area corresponds to a symptomatic tree.

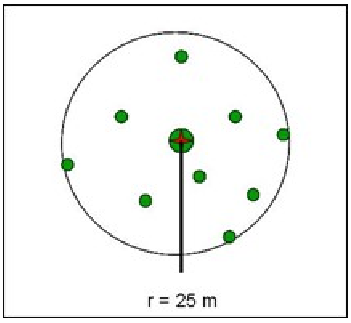

Fig. 1: A schematic representation of a sampling area; noteworthy is that the number of trees (green circles) within each sampling area is random, depending on the quantity of plants around the central tree.
Fig. 1: Rappresentazione schematica di un'area di saggio; si noti che il numero degli alberi (cerchi in verde) all'interno di ciascuna area è casuale poiché dipende dalla densità del popolamento attorno all'albero centrale.

For each Regional Park, the amount as well as the distribution of sampling areas were influenced by the local ecological features and the uniformity of health conditions, so that a major number of sampling areas and trees were circumscribed in locations where decay was more severe than in others.
For each sampling area, the vegetation and the health conditions of trees were defined; the latter ones were established on the basis of the observed decay symptoms. In particular, for each tree, three decay parameters namely 1) the canopy transparency, 2) the wilting and 3) the defoliation were considered and established by splitting the plant's foliage into three parts (a lower, an average and an upper part). Moreover, if present, specific foliar symptoms (*e.g.*: chlorosis, necrosis, discoloration, wilting, leaf roll, mold, spots) as well as

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decay of woody parts (*e.g.*: lesions, cankers, dry rot, fruiting bodies, emission of exudates) caused by both biotic and abiotic stresses were registered.

Once identified, symptoms of decay were photographed and appropriately described for each tree; moreover, GPS coordinates, height, and diameter at breast height (at 1.2 m from collar) were stored.

Starting from the aforementioned data, the sanitary conditions of each sampling area were expressed by using two parameters: (1) the phytosanitary class (PC) and (2) the incidence of the phytosanitary class within a sampling area (I%).

The phytosanitary class (PC) is a numerical index describing the health conditions of a tree and may assume values ranging from 0 to 4, corresponding with an increasing intensity of damage. In particular, this value summarizes a visual scale of decline (Council regulation EEC N.3528/86 on the protection of forests in the Community against atmospheric pollution – Bruxelles 1986), based on two parameters namely (i) defoliation and (ii) discoloration of leaves. In this study, the scale has been modified by including symptoms of trunk and main roots (Tab. 1). Assuming that the symptoms detected on trees within a sampling area were quite homogenous and attributable to a specific PC, the sampling area was described by using the phytosanitary class determined for its trees.

Tab. 1: Description and features of the different phytosanitary classes. Damage on canopy, information on defoliation and discoloration parameters are also reported.

Tab. 1: Descrizione e caratteristiche delle diverse classi fitosanitarie con le indicazioni dei principali parametri: danni sulla chioma, defogliazione e decolorazione.

Phytosanitary class	Description	Phytosanitary class features	Defoliation	Discoloration
0	Healthy plant	No visible changes of the considered parameters.	-	-
1	Weak decay of canopy	Weak visible changes of branches and/or leaves - absence of epicormic shoots.	10-25%	10-25%
2a	Evident decay of canopy	Evident visible changes of branches and/or leaves - absence of epicormic shoots.	26-60%	26-60%
2b	Evident decay of trunk	Evident visible changes mainly on trunk and/or root system	-	-
3	Serious decay of canopy, trunk and roots	Serious visible changes of all plant organs as canopy/trunk/root system - presence of epicormic shoots.	>26%	>26%
4	Death plant	Death of all plant organs.	-	-

By evaluating the percentage of trees exhibiting the characteristic symptoms of the specific PC within a sampling area, the incidence (I%) of a given PC in the sampling area was calculated. In detail, the incidence of each PC in that specific area could assume one of the following percentage values: <10%; 10-25%; 26-60%; 61-90%; >90%.

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Finally, among all sampling areas, *permanent sampling areas*, defined as sites that show over 50% of incidence of trees classified in PC 2a, 2b, 3, or the area designated as PC 4, were selected with the aim of monitoring intensively (at least one survey per year) the health conditions of stands characterized by severe symptoms of decay.

Results

Overall, during the monitoring activities, 81 sampling areas were circumscribed, among which 54 in oak stands and 27 in beech. In detail, the sampling areas were distributed in the three Sicilian Regional Parks under study as follows: 33 into the Nebrodi Park (15 in oak and 18 in beech stands), 23 into the Madonie Park (20 in oak and 3 in beech stands), and 25 into the Etna Park (19 in oak and 6 in beech stands) (see Tab. 2). Among all sampling areas, 68 were characterized by trees showing different symptoms of decay (including phytosanitary classes 1-4), while in 13 (8 of which in the Etna Park) only asymptomatic trees were recognized (classified in PC 0). Details on phytosanitary classes and their distribution into the studied Regional Parks are reported in Tab. 3.

Tab. 2: List of sampling areas circumscribed in the three Regional Parks along with information on municipality and locality. Sampling areas are labeled by using an alphanumeric code, with progressive Arabic numbers preceded by a letter indicating the Park (M: Madonie; E: Etna; N: Nebrodi).
Tab. 2: Aree di saggio individuate nei diversi comuni dei tre Parchi Naturali della Sicilia. Le aree sono indicate con un codice costituito da una lettera e un numero (M: Madonie; E: Etna; N: Nebrodi).

MADONIE REGIONAL PARK				
Municipality	**Locality**	**Oak sampling area ID**	**Beech sampling area ID**	**N. of sampling areas**
Castelbuono	Piano Sempria	M1 – M2 – M3 – M6		4
	Piano Pomo	M4 – M5		2
	Bosco Cava	M12 – M13 – M14 – M15 – M16		5
Collesano	Pomieri	M7 – M8 – M9 – M10 – M11		5
Isnello	Piano Cervi		M20 – M21	2
	Portella Piana	M22		1
Petralia Sottana	Serre di Corco	M17 – M18 – M19		3
	Piano Battaglia		M23	1
TOTAL:		**20**	**3**	**23**
ETNA REGIONAL PARK				
Municipality	**Locality**	**Oak sampling area ID**	**Beech sampling area ID**	**N. of sampling areas**
S. Alfio	Cerrita	E1 – E2 – E4		3
	Cubania	E5 – E6 – E7 – E8		4
Milo	Bosco Nicolosi	E3		1
Linguaglossa	Caserma Pitarrone	E9		1
	Mandra del Re	E10		1
Randazzo	Monte Crisimo	E11		1
	Parco Sciarone	E12		1
	Felloni della Nave	E13		1
	Monte Spagnolo		E22	1
	Monte Santa Maria		E23	1
Maletto	Feudo Soprano	E14		1
	Poggio del Monaco	E15		1

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Zafferana Etnea	C.da Ilice	E16		1
Biancavilla	Rugoro Grosso	E17		1
Adrano	Prato Fiorito	E18		1
Bronte	Mandra		E19 – E20 – E21	3
	Monte La Nave	E25		1
Castiglione di Sicilia	Timpa Rossa		E24	1
TOTAL		**19**	**6**	**25**
NEBRODI REGIONAL PARK				
Municipality	**Locality**	**Oak sampling area ID**	**Beech sampling area ID**	**N. of sampling areas**
Randazzo	Bosco del Flascio	N1 – N2 – N3		3
	Fago Scuro		N22	1
Cesarò	C.da Buffali	N4		1
	C.da Cicogna		N5	1
	Monte Sollazzo		N6	1
	C.da Sollazzo		N19	1
	Monte Soro		N11 – N12	2
	Lago Maulazzo		N13	1
	Pizzo dell'Incudine	N16		1
	Vallone Bello Ventre		N17	1
	Serra Stricatori		N18	1
San Fratello	Pizzo Muto		N7	1
	C.da Porcaria	N8		1
	C.da Crocetta	N9		1
	Monte Fossa del Lupo		N10	1
Alcara Li Fusi	Bosco Saracina		N14	1
Bronte	Segheria	N15		1
Troina	C.da Scarna		N20	1
	C.da Fontana Bianca	N21		1
Longi	Bosco Mangalaviti		N23 – N33	2
Maniace	Bosco Petrosino	N24		1
Capizzi	Pizzo Buschi		N25	1
	Vallone Brunelli		N26	1
	Pizzo Manca Badia		N30	1
Caronia	Tassita		N27	1
	Cozzo della Testa	N28		1
	Piano Re	N29		1
S. Agata di Militello	Pizzo Monachello	N31		1
Militello Rosmarino	C.da Fontana Impiccia		N32	1
TOTAL		**13**	**20**	**33**

Tab. 3: Distribution of the recognized phytosanitary classes within the sampling areas belonging to the three Regional Parks studied.
Tab. 3: Distribuzione delle classi fitosanitarie individuate nelle aree di saggio dei popolamenti di faggio e di querce dei tre parchi regionali siciliani.

Regional Parks	**Phytosanitary classes**					
	0	**1**	**2a**	**2b**	**3**	**4**

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Etna	Oak stands	5	2	1	8	3	-
	Beech stands	3	-	-	3	-	-
	Total	8	2	1	11	3	-
Madonie	Oak stands	1	5	7	2	4	1
	Beech stands	1	-	1	1	-	-
	Total	2	5	8	3	4	1
Nebrodi	Oak stands	2	7	3	-	3	-
	Beech stands	1	5	4	4	4	-
	Total	3	12	7	4	7	-

In the Nebrodi Park, on a total of 33 sampling areas, 30 showed trees with severe symptoms of decay, mainly related to woody parts and canopy (PC 2.a, 2.b and 3). In the Madonie Park the greatest frequency of sampling areas characterized by decaying trees was observed; in particular, among the 23 circumscribed sampling areas, 21 exhibited trees with severe symptoms of decay with a preponderance of class 1 and class 2.a (*i.e.*: weak and evident decay on canopy, respectively). Otherwise, in the Etna Park, the lowest frequency of sampling areas characterized by declining trees was observed. Moreover, in the Etna Park, the frequency of damage on canopy was significantly less than the Nebrodi and Madonie Parks; in fact, only 12% of sampling areas were attributable to phytosanitary classes 1 and 2.a. By contrast, significant damage was observed on woody parts; in fact, in 64% of sampling areas characterized by declining trees, 11 out of 17 were classified as 2.b phytosanitary class.

Sanitary conditions of oak stands

The monitoring activity carried out in the three Sicilian Regional Parks revealed a generalized severe decay of oak stands; in fact, 85% of sampling areas in oaks showed symptomatic trees (*i.e.*: 46 of 54).

The distribution of phytosanitary classes, along with the different typologies of oak forests, is summarized in Fig. 2. It is interesting to note that only the mesophile oak stands exhibited symptoms of decay attributable to all the phytosanitary classes (with the majority classified in 1, 2.a and 2.b). Regarding the geographical distribution of the phytosanitary classes in the three Regional Parks (Tab. 3), all classes were identified in the oak stands belonging to the Madonie Park, while in the Nebrodi Park damage was mainly observed on the canopy with a preponderance of trees classified in 1 and 2.a PC. The most severe decay was observed on symptomatic trees belonging to oak stands of the Etna Park (*i.e.*: 2.b and 3 PC), even if in this park the majority of sampling areas were characterized by asymptomatic trees (*i.e.*: PC 0).

With respect to the typology of damage recognized in the monitored oaks of the Regional Parks, in the Nebrodi and Madonie Parks, symptoms typically related to a generalized decline of oak trees mainly affecting canopy (*i.e.*: PC 1 and 2.a) were observed; in the latter, the most common were represented by a reduced number of new branches, local defoliation, wilting of branches, as well as specific leaf lesions, such as necrotic and chlorotic spots, and, possibly, damage caused by phytophagous insects (*e.g.*: erosion along the leaf margin and leaf strains). Damages affecting woody parts (summarized in PC 2.b) were clearly exhibited by turkey and mesophile oaks in the Etna Park; in detail, the symptoms were represented by hyperplasia, bark stripping and splitting, woody-rot, red-brown areas on the bark, necrosis of tissues, and

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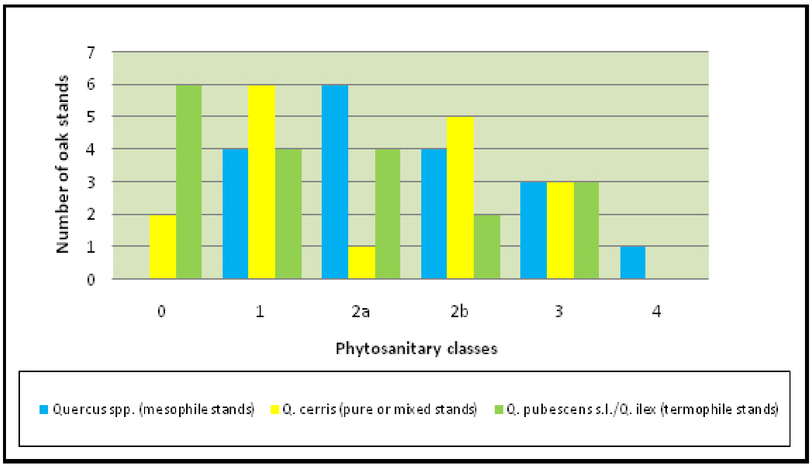

Fig. 2: Distribution of phytosanitary classes in the sampling areas along with the different typology of oaks in the Regional parks.
Fig. 2: Distribuzione delle classi fitosanitarie nelle aree di saggio per le diverse specie di quercia presenti nei popolamenti dei parchi siciliani.

production of exudates. Finally, serious decay of canopy, trunk and roots (described in PC 3) was observed in all the parks studied. In detail, pubescent and turkey oaks showed damage on canopy and decay of woody parts. Among the latter one, bark splitting mainly occurred; this kind of lesion was usually located about 30-50 cm above the collar and deepened on the trunk, exhibiting various sizes and producing brown exudates; sometimes, by removing the bark, necrosis of internal wood was also observed.

The incidence of the phytosanitary classes within the 54 sampling areas is summarized in Fig. 3. Data clearly indicate that phytosanitary classes 2.a and 2.b, which include symptoms of decay mainly related to canopy, are the most abundant, recurring in 21 of the total of analyzed sampling areas. Within the latter group, the incidence of the aforementioned PC classes ranged from 26-60% (for 7 sampling areas) to 61-90% (for 5 sampling areas). The statistical incidence of classes characterized by severe symptoms related to canopy clearly suggested a generalized state of decay of oak stands. This evidence is supported also by the relevant number of sampling areas characterized by PC 3, with an incidence of more than 90% in one of

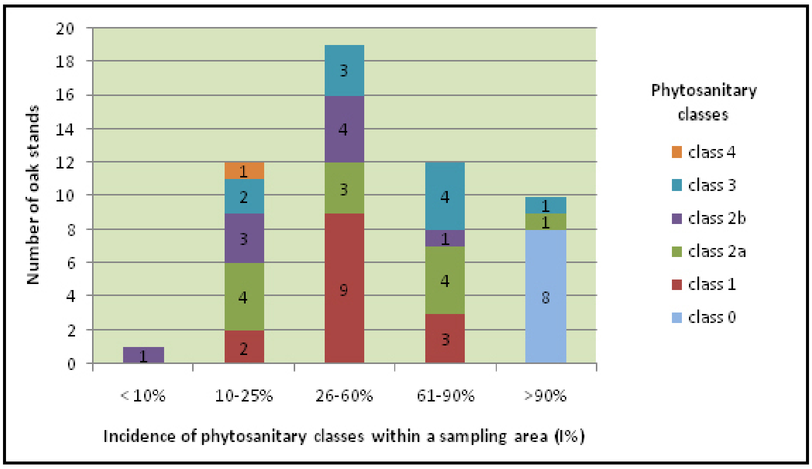

Fig. 3: Incidence (I%) of the phytosanitary classes within the sampling areas in oak stands.
Fig. 3: Incidenza (I%) delle diverse classi fitosanitarie nelle aree di saggio dei popolamenti di quercia.

them. Finally, besides the relatively low incidence (10-25%), one sampling area localized in the Madonie Park exhibited the death of trees and in fact it was classified as PC 4.

In Tab. 4, phytosanitary classes of each sampling area along with the incidence (I%) indicate the overall sanitary conditions of oak stands. A relevant number of sampling areas (4 in the Madonie Park, 8 in the Etna Park and 6 in the Nebrodi Park) exhibit a severe decline, as characterized by an incidence of more than 50% of phytosanitary classes 2.a, 2.b, and 3, and with trees classified in PC 4. On the basis of the health conditions of trees of these sampling areas, these oak stands were selected as permanent sampling areas (see Fig. 4).

Tab. 4: Overview of the sanitary conditions of the oak stands analyzed in the three Regional Parks. For each oak stand, the sampling area code (ID), the phytosanitary class (PC) and the relative incidence (I%) are reported. Permanent sampling areas are in bold.
Tab. 4: Sintesi della situazione fitosanitaria dei boschi di quercia nei tre parchi regionali siciliani. Per ciascun tipo di popolamento sono indicate le aree di saggio e per ciascuna di esse la classe fitosanitaria (PC) e la relativa incidenza (I%). In neretto sono indicate le aree di saggio permanenti.

Madonie Regional Park			
Typology of oak stands	**ID**	**PC**	**I%**
Quercus spp. *F. sylvatica*	M18	1	26-60
	M19	1	26-60
	M5	2a	10-25
	M2	**2a**	**26-60**
	M6	2b	10-25
	M1	3	10-25
	M4	3	10-25
	M3	**4**	**10-25**
Quercus spp.	M7	1	26-60
	M17	1	26-60
	M9	2a	10-25
	M11	2a	10-25
	M8	2a	26-60
	M10	2a	26-60
Q. pubescens *Q. ilex*	M14	0	>90
	M13	1	61-90
	M12	2b	26-60
	M16	3	26-60
	M15	**3**	**61-90**
Q. ilex/Q. suber	**M22**	**2a**	**61-90**

Etna Regional Park			
Typology of oak stands	**ID**	**PC**	**I%**
Quercus spp. *F. sylvatica*	E7	2b	10-25
	E8	2b	10-25
	E9	2b	10-25
Q. cerris *Q. pubescenss.l.*	**E1**	**2b**	**26-60**
	E2	**2b**	**26-60**
	E4	**2b**	**20-40**
	E5	**2b**	**61-90**
	E6	**3**	**61-90**
Q. pubescenss.l.	E10	0	>90
	E11	0	>90
	E12	0	>90
	E14	0	>90
	E17	0	>90
Q. pubescens s.l. *Q. ilex*	E15	1	10-25
	E25	**2a**	**>90**
	E3	2b	<10
Q. ilex/Quercus spp.	**E16**	**3**	**61-90**
Q. ilex	E18	1	26-60
	E13	**3**	**>90**

Nebrodi Regional Park			
Typology of oak stands	**ID**	**PC**	**I%**
Q. cerris *F. sylvatica*	N20	1	26-60
	N21	1	26-60
	N32	1	26-60
Q. cerris	N3	0	>90
	N16	0	>90
	N29	1	61-90
	N1	**3**	**26-60**
	N2	**3**	**26-60**
Quercus spp. *Q. gussonei*	**N15**	**2a**	**61-90**
	N31	**3**	**61-90**
Q. cerris *Q. pubescens s.l.*	N4	1	26-60
	N28	1	26-60
Q. pubescens s.l.	N24	1	10-25
Q. pubescens s.l. *Q. ilex*	**N8**	**2a**	**61-90**
	N9	**2a**	**61-90**

Sanitary condition of beech stands

Globally, the 27 sampling areas assessed in beech stands showed better health conditions than that of the oaks; in fact, about 19% did not show symptoms of decay (*i.e.*: 5 sampling areas were classified in PC 0) and no sampling areas were classified in PC 4.

The phytosanitary class 2.b was the most abundant (covering 8 sampling areas), with a low-medium incidence (in the majority of sampling areas it was always less than 60%).

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The higher value of phytosanitary class was attributed to only 4 sampling areas, with a medium-high incidence ranging from 26-60% to 61-90%. It is noteworthy that all the aforementioned sampling areas were localized in the Nebrodi Park (see Tab. 5 and Fig. 4), suggesting the need for special attention to beech stands of this Regional Park. Also in this case, the sampling areas N7, N10, N22 and N23 were selected as permanent sampling areas.

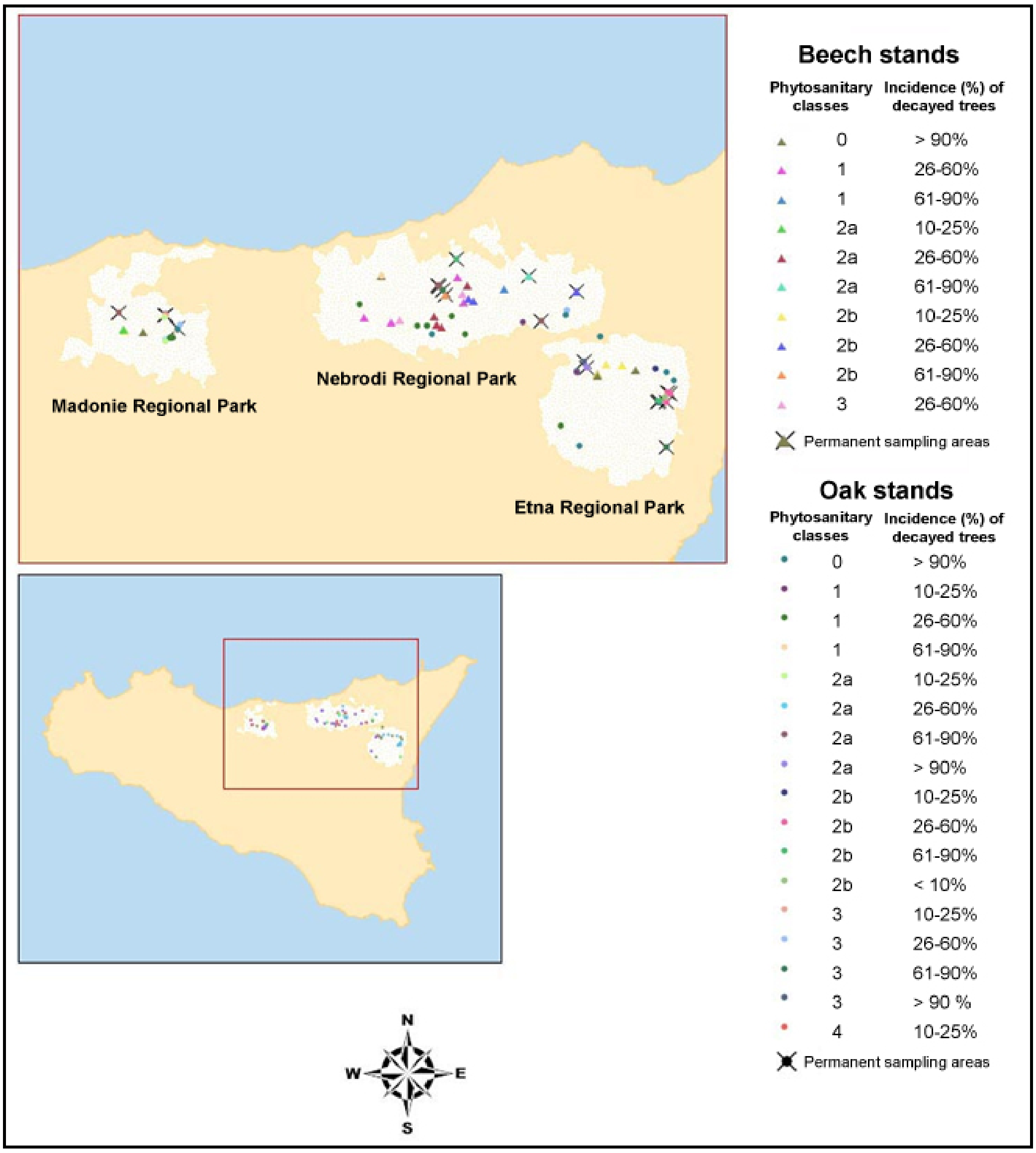

Fig. 4. Geographical distribution of the analyzed sampling areas in oak and beech stands. For each sampling area, the relative phytosanitary class along with its incidence (I%) is reported. The cross indicates the sampling areas selected as permanent.

Fig. 4. Distribuzione geografica delle aree di saggio di quercia e faggio monitorate con l'indicazione delle classi fitosanitarie e dell'incidenza (I%). Nella mappa sono anche indicate le aree di saggio permanenti.

Signs and symptoms of fungal infections

As mentioned previously, the health conditions of a stand are influenced by both abiotic and biotic stresses. Among the latter ones, fungal pathogens represent a serious cause of damage. In the framework of the

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Tab. 5: Overview of the sanitary conditions of the beech stands analyzed in the three Regional Parks. For each oak stand, the sampling area code (ID), the phytosanitary class (PC) and the relative incidence (I%) are reported. Permanent sampling areas are in bold.
Tab. 5: Sintesi della situazione fitosanitaria dei boschi di faggio nei tre parchi regionali siciliani. Per ciascun tipo di popolamento sono indicate le aree di saggio (ID) e per ciascuna di esse la classe fitosanitaria (PC) e la relativa incidenza (I%). In neretto sono indicate le aree di saggio permanenti.

Madonie Regional Park				**Etna Regonal Park**				**Nebrodi Regional Park**			
Typology of beech stand	**ID**	**PC**	**I%**	**Typology of beech stand**	**ID**	**PC**	**I%**	**Typology of beech stand**	**ID**	**PC**	**I%**
F. sylvatica	M23	0	>90	*F. sylvatica*	E19	0	>90	*F. sylvatica*	N30	0	>90
	M21	2°	10-25		E20	0	>90		N5	1	26-60
	M20	2b	10-25		E24	0	>90		N26	1	26-60
					E21	2b	10-25		N33	1	61-90
					E22	2b	10-25		N14	2a	26-60
					E23	2b	10-25		N17	2a	26-60
									N23	**2a**	**61-90**
									N11	2b	26-60
									N12	2b	26-60
									N7	**2b**	**61-90**
									N13	3	26-60
									N19	3	26-60
								F. sylvatica Taxus baccata	N27	1	26-60
								F. sylvatica Ilex aquifolium	N18	2a	26-60
									N10	**3**	**61-90**
								F. sylvatica Q. cerris	N32	1	26-60
									N22	**2b**	**26-60**
									N25	3	26-60

monitoring activities carried out in the Sicilian Regional Parks, some of the symptoms and signs observed on both oak and beech stands can be clearly associated with fungi.
In detail, in oak stands, basidiocarps of *Fistulina hepatica* (Schaeff) With. and *Polyporus* sp. Fr., often causing dry rot (Fig. 6 a-b), were recognized on several severely decayed oaks in sampling areas classified as PC 3 in the Madonie Park. On highly damaged evergreen oaks of the Etna Park and circumscribed in sampling areas with PC 3 (*e.g.*: E16), basidiocarps of *Ganoderma lucidum* (Curtis) Karst., (common causal agent of root rots) (Fig. 6.c) were observed on the collar.
Ascocarps of *Biscogniauxia mediterranea* (De Not.) Kuntze, the causal agent of charcoal canker, were recognized on trunks of several oaks in the Nebrodi and Etna Parks. In particular, they were observed both on asymptomatic and decayed trees of pubescent oaks (*e.g.*: in E25 and N15 sampling areas) (Fig. 6.d), as well as on asymptomatic turkey oaks (*e.g.*: in N31 sampling area).
A typical subcortical white mycelium of *Armillaria* sp. Fr. was observed on the collar of several *Quercus cerris* L. belonging to the Nebrodi Park (*e.g.*: in N2 sampling area). Finally, leaf lesions caused by *Mycrosphaera alphitoides* Griff. et Maubl. were observed on adventitious shoots of pubescent oaks (*e.g.:* in E25 sampling area) (Fig. 6.e-f).
As for the beech stands, stromata of *Biscogniauxia nummularia* (Bull.) Kuntze, the ascomycota causal agent of charcoal canker (Fig. 7.a) were recognized on trunks and on the main branches of beech trees belonging to several sampling areas classified in PC 2.b; in particular, the affected trees showed the following symptoms of decay: defoliations, bark splitting, and bark cankers. This fungus recurred in 11 of 27 sampling areas.

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Moreover, in the Nebrodi Park, *Biscogniauxia nummularia* (Bull.) Kuntze was identified on holly trees (*Ilex acquifolium* L.) belonging to a mixed beech stand.

Basidiocarps of *Fomes fomentarius* (L.) Kichx, the causal agent of dry rot, (Fig. 7.b) were observed on the collar of beech trees belonging to the Nebrodi Park (*e.g.*: in N25 sampling area).

Finally, bark cankers associated with *Neonectria radicicola* Gerlach & L. Nilsson infection (Fig. 7.c-d) were observed on the collar of several beech trees in the Madonie Park (*e.g.*: in M20 sampling area). It is worthy of note that the identification of this pathogen was performed by analyzing the colony morphology as well as the conidia features of a pure culture isolated on PDA medium, as specific symptoms were not observed on the decaying trees.

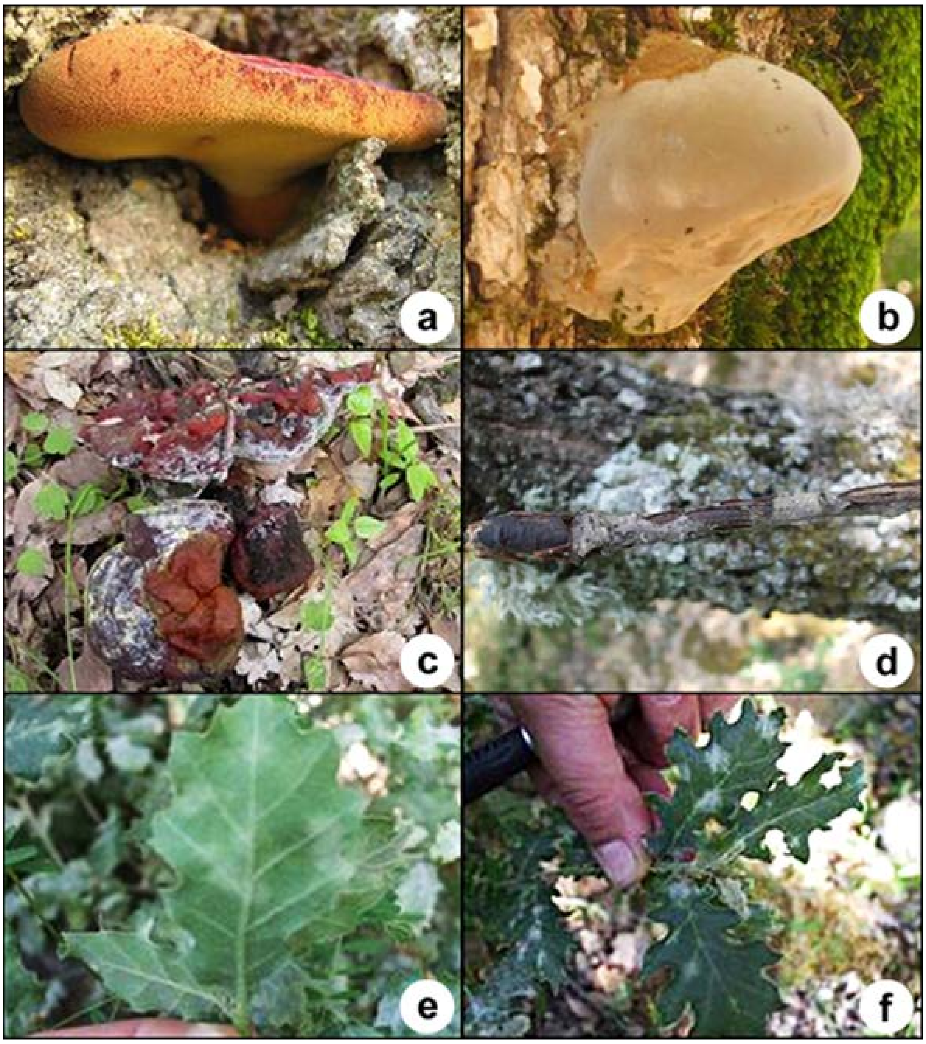

Fig. 6: Examples of damage caused by fungal pathogens in oaks. (a) Basidiocarps of *Fistulina hepatica* and (b) *Polyporus* sp. on trunk; (c) root rot by a *Ganoderma lucidum* infection on holm oak; (d) charcoal canker by a *Biscogniauxia mediterranea* infection on branches of pubescent oak; (e-f) *Microsphaera alphitoides* infections on adventitious shoots of pubescent oak.

Fig. 6: Esempi di sintomi e segni causati da patogeni fungini su quercia. (a) Carpofori di *Fistulina hepatica* e (b) *Polyporus* sp. sul fusto; (c) marciume radicale da infezioni di *Ganoderma lucidum* su leccio; (d) Stroma carbonioso di *Biscogniauxia mediterranea* su rami di roverella; (e-f) infezioni di *Mycrosphaera alphitoides* su giovani ricacci di roverella.

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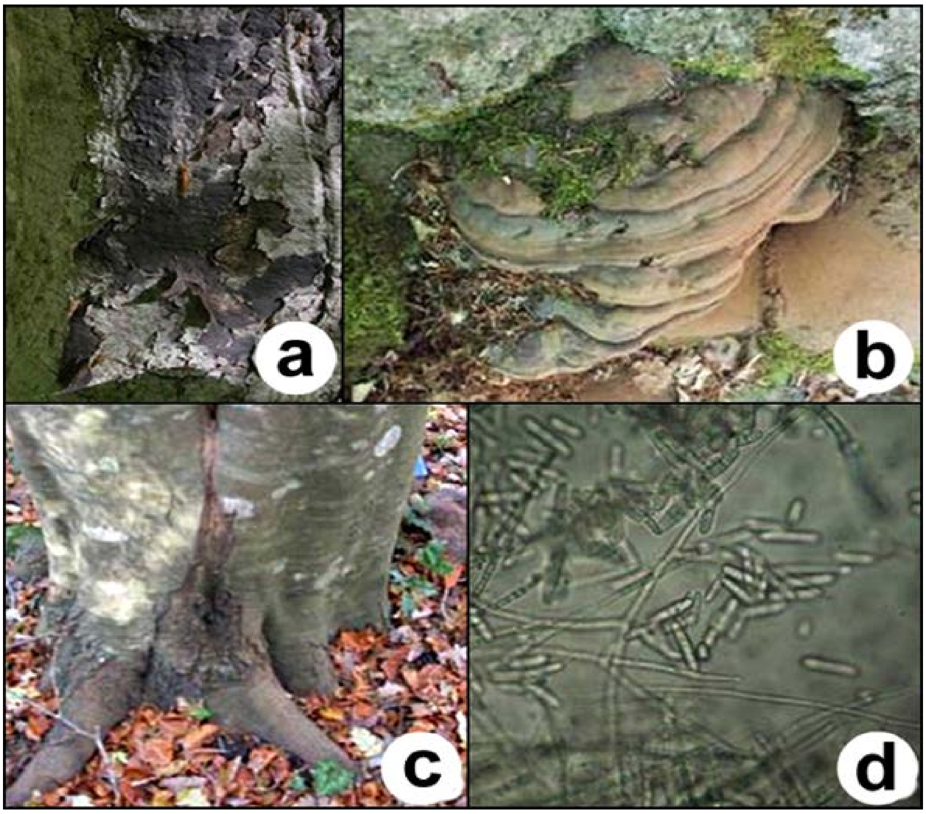

Fig. 7: Examples of damage caused by fungal pathogens in beech trees. (a) Stromata of *Biscogniauxia nummularia* on a beech tree trunk.; (b) basidiocarp of *Fomes fomentarius* on the collar of a beech tree; (c) bark cankers caused by a *Neonectria radicicola* infection on the trunk of a beech tree and (d) conidia of *N. radicicola*.
Fig. 7: Esempi di sintomi e segni causati da patogeni fungini su.faggio (a) Stromi di *Biscogniauxia nummularia* sul fusto di alberi di faggio; (b) Basidioma di *Fomes fomentarius* alla base del tronco di un albero di faggio; (c) Cancri alla base del tronco su albero di faggio causati da *Neonectria radicicola* e (d) conidi di *N. radicicola*.

Discussion

In this study, surveys carried out in the Sicilian Regional Parks highlighted a generalized decline of oak and beech forests. In fact, the majority of the circumscribed sampling areas were characterized by the presence of numerous damaged trees exhibiting severe symptoms of decline.

In general, beech stands were in better condition, with the exception of the Nebrodi Park, where the worst health conditions were recognized with more than 90% of the circumscribed sampling areas characterized by symptomatic trees. In oak forests, the worst health conditions were shown by turkey and mesophile stands belonging to the Etna and Madonie Parks, in which trees were mainly characterized by severe symptoms of decay of the canopy (classified in PC 1 and 2.a).

Even if a significant disturbance due to pasture activities was recognized (responsible for soil compaction, pauperization of undergrowth and decrease of adventitious shoots), the symptoms of decay observed on canopy are more probably due to the so-called *generalized decline of forest stands* (DELATOUR, 1983; MANION, 1991; THOMAS *et al.*, 2002). This is a complex typology of decay resulting from the interaction between abiotic (mainly unsuitable climatic conditions) and biotic stresses, and characterized by predisposing, trigger and concomitant factors.

Among predisposing factors, the wind direction as well as its periodicity have to be mentioned, especially considering its influence on exposed trees. For example, during the summer, the Sirocco hot winds determine

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the sudden increment of the evapotranspiration that consequently increases the demand for water in oak trees, which is in contrast with the typical local summer aridity.

The prolonged dry season of the last two decades may be considered a trigger stress factor for mesophile oak stands. Finally, pests and opportunist fungal pathogens represent the most common concomitant factors. In particular, fungal pathogens mainly intervene on plants stressed by predisposing and trigger factors, even causing their death.

The results obtained by the monitoring activities on oak and beech stands in the Sicilian Regional Parks have highlighted the crucial role of the fungal pathogens in influencing the health conditions of the analyzed declining trees. The recognized fungal pathogens represent the most common fungal species in temperate and Mediterranean forests. According to the obtained results, they seem to play a quite relevant role in the decline of oak and beech forests of the Sicilian Regional Park.

In several stands, a high incidence of endophytic fungi, as *Biscogniauxia mediterranea* (De Not.) Kuntze (mainly present in the oak stands) and *B. nummularia* (Bull.) Kuntze (beech stands), were recognized. These species are notoriously associated with the generalized decline of forests (GRANATA and AGOSTEO, 1991; CELLERINO *et al.*, 1991; FRANCESCHINI *et al*., 2000; CELLERINO *et al.*, 2002; FRANCESCHINI *et al.*, 2002; SAIKKONEN, 2007; BONCALDO *et al*., 2007). In fact, even if neutral or symbiotic relationships represent the most common biotic interactions established between endophytic fungi and trees, several studies testified that particular environmental conditions might promote the pathogen behavior of the endophytic fungi (KOWALSKI, 1991; LUISI *et al*. 1995; VANNINI *et al*., 1996; VANNINI, 1998; ANSELMI *et al*., 2000; RAGAZZI, 2004). In particular, endophytic fungi are considered by several authors highly pathogenic towards trees afflicted by water stress, so that they may be used as bio-indicator of water stress in forest stands (NUGENT *et al.*, 2005).

Among fungi causing rots, the presence of *Armillaria* sp. Fr. and *Ganoderma lucidum* (Curtis) Karst., which are typical causal agents of root and collar rot, was recognized. Usually, the causal agents of rots, such as *Polyporus* sp. Fr., *Fistulina hepatica* (Schaeff) With. and *Fomes fomentarius* (L.) Kichx, are symptomatic of a progressive ageing of trees. However, in the Sicilian forests, they seem to be strictly related to the progressive decline and, sometimes, to the death of the trees.

Even though for the majority of symptoms the causal agents were identified, in some cases, the etiology of numerous concomitant symptoms affecting canopy both in oak and beech trees could not be established; however, some hypotheses can be proposed. The severe decay observed on oak stands belonging to the Etna Park as well as on beech in the Nebrodi Park was globally characterized by foliar thinning, foliar chlorosis, small leaves, defoliation, wilting of branches, and growth of epicormic shoots. The concomitant manifestation of the aforementioned symptoms suggests a generalized decline of root system, which could be related to the action of soil-borne pathogens such as several *Phytophthora* species. In fact, recent and ongoing studies on *Phytophthora* have evidenced the role of this pathogen as causal agent of numerous diseases affecting oak and beech forests in Europe and America (RAGAZZI *et al.*, 1989; BRASIER, 1996; RIZZO and GARBELOTTO, 2003; GARBELOTTO and HUBERLI, 2006; BALCI *et al.*, 2010; JUNG, 2009; JUNG *et al.*, 2000; JUNG and BLASCHKE, 2004; JUNG *et al.*, 2013; Jung *et al.*, 2016; SCANU *et al.*, 2013; SCANU *et al*., 2014).

Conclusions

For the first time, a systematic monitoring of the health conditions of Sicilian oak and beech forests has been carried out in the framework of the Forestry Management Plan bestowed by the Sicilian Regional

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Department for Agriculture and Forestry. The chosen method has been deduced from a well-established approach successfully applied for the methodical studies of the health conditions of forest stands in other Italian regions (CENNI *et al.*, 1998). The overall data have made it possible to define the global sanitary conditions of oak and beech stands in the Sicilian Regional Parks, also supplying information on the main causal agents of severe symptoms on roots and trunks. In these perspectives, the research could be used as a support case for the assessment of appropriate management planning for the preservation of the local forests cared for by the Regional Phytosanitary Forests Institute (SIDOTI, 2011). In this way, the standards required and suggested by programs such as PEFC (Programme for Endorsement of Forest Certification Scheme) and FSC (Forest Stewardship Council) could be reached in the Sicilian Regional Parks.

Despite the really promising results of the present study, the current research is far from its end, especially in the framework of the etiological definition of some symptoms related to the action of soil-borne pathogens such as *Phytophthora* spp.. The first step in the agenda will consist of performing sampling campaigns by using specific isolation methods (*i.e.:* from soil samples using baiting methods, from water bodies using baiting methods, from infected roots, from bark samples) and in analyzing environmental samples (soil, water, vegetable structures) through molecular methods (ERWIN and RIBEIRO, 1996; SCIBETTA *et al.*, 2012). Only in this way will it be possible to better understand and eventually define the geographical distribution of *Phytophthora* species in the studied forests as well as the possible role of this pathogen in the decline of oak and beech stands in the Sicilian natural parks.

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