IUFRO Conference on

COLLECTING and ANALYZING INFORMATION for SUSTAINABLE FOREST MANAGEMENT and BIODIVERSITY MONITORING with special reference to MEDITERRANEAN ECOSYSTEMS

PROCEEDINGS

4-7 December 2001
Palermo, Sicily (Italy)

Edited by
Piermaria Corona, Sten Folving, Marco Marchetti

EUROPEAN COMMISSION
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FOREWORD

The idea of organizing a Conference on "Collecting and analyzing information for sustainable forest management and biodiversity monitoring with special reference to Mediterranean ecosystems" was conceived by Piermaria Corona, Sten Folving and Marco Marchetti, as a main issue of their activities within IUFRO Working Parties 4.02.05 (Remote Sensing and World Forest Monitoring) and 4.02.06 (Resource Data in the Boreal and Temperate Regions).

The need of reviewing and discussing recent improvements of forest inventory/monitoring was acknowledged to cope with the required assessment and understanding of ecosystem attributes on a global environmental and georeferenced scale. Properly targeted application improvements must be primarily focused on technical advancements in a broad sense. Changes in land cover and in other ecosystem features have a direct impact on the social expectations concerning forests, especially for its links with nature conservation, global climatic changes and recreation activities. On one hand, the increasing concern of people, researchers and public administration for the values of such environments has enhanced the need for reliable and standardised information on forest attributes: statistics, georeferenced data-bases, thematic cartography, etc. On the other hand, inventories are often not fully exploited for actual forest planning and control. This is distinctively true for the issues related to sustainable forest management. Within such a framework, fostering sound forest inventory and monitoring initiatives and extension encourages the technical and organisational development of the whole forestry sector. An increasing impact on forest inventory and monitoring is expected by the international directives posing the problem of assessing habitat and ecosystem changes with respect to biodiversity conservation and forest externalities. In Mediterranean countries, reliable and internationally comparable information on forest health and protection, wildfires and biodiversity is largely missing or unsatisfactory. This state is in contrast with the wood-production-oriented information characteristically provided by current forest inventory and monitoring procedures.

As a result, the target of the Conference was to give participants hands-on workshop exchanges and experiences about inventory/monitoring problems and potential. Special (but not exclusive) reference was made to Mediterranen forest and other wooded ecosystems, and techniques like remote sensing and spatial analysis in GIS environment. The major objectives of the Conference were:

- review the state-of-the-art of forest inventory data and methodology, with special reference to Mediterranean ecosystems, remote sensing and spatial analysis;
- review inventory/monitoring techniques relevant to high forest landscape heterogeneity and forthcoming technologies;
- review mensuration and information technology advances for distinctive issues such as monitoring wildfires, biomass estimation, grazing pressure on forests, etc.;
- discuss the possible connecting role of landscape ecology and the inventory implementation of habitat classification approaches in the view of biodiversity assessment;
- facilitate cooperation between Mediterranean countries, enhancing externalities perspective development as the greater contribution to natural and seminatural areas management in such environments;
- produce summary of discussions and conclusions to be included in this Conference proceedings.

These objectives were found interesting for 101 persons who attended the Conference in Palermo coming from 17 countries, mostly European, but also from Africa, Asia, Australia, and Central America.

All the Conference sessions were plenary. The diversity and quality of invited and voluntary papers and posters showcasing research advances and experiences for different types of forest inventory and monitoring issues were high. Lively discussions on the presented issues were held at the end of each session, and a global synthesis discussion was held on the final day. A post-Conference excursion was organized on the Mt. Etna, to have an experience of the attractive features of volcanic environment, and of landscapes representing almost all the types of Sicilian forest ecosystems.

We would like expressing our special thank to: the participants for their valuable contribution to the Conference, the members of Scientific Committee for the efforts in planning the Conference program and reviewing the papers, the chairpersons for their activitiy during the Conference, the Organizing Committee and all the volunteers from the Palermo University for their job in setting up all the practical matters that made the Conference such an enjoyed event.

This book does not present all oral and poster presentations in the respective sessions. Papers more directly linked to Mediterranean ecosystems and/or biodiversity issues have been collected in these proceedings. Nevertheless, the volume covers more than 50% of the presentations. The articles are presented as provided by the Authors

Piermaria CORONA, Sten FOLVING, Marco MARCHETTI

Structural types in pure beech and mixed beech-fir woods in Mediterranean environment and their relationships to the silvicultural practices

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Abstract
The authors present the results of a study conducted in pure beech and mixed beech-fir woods on the southern slopes of the Aspromonte and highlight the extent to which silvicultural treatments have affected the structural profile.

Keyworks: structural types, complexity, beech woods, beech-fir woods

1. Introduction

Structure reflects the manner in which the individuals in a stand are distributed in time and space in relation to the stresses deriving from processes of adaptation, cooperation and competition as a consequence of evolution or silvicultural treatments.
A structural analysis makes it possible to identify and define the forest's evolutionary status and the system's level of complexity (Ciancio and Nocentini 1994).
Determining the structure of a forest first requires a definition of its profile in order to distinguish whether it is in planes or layers. A plane profile distinguishes a structural type characterized by plants belonging to a single age class (even-aged forests) with dimensions – primarily height – that are significantly differentiated either by intrinsic features or casual events. The layered profile, on the other hand, represents a structural type characterized by plants belonging to different age classes (uneven-aged forest) (Agrimi et al. 1991).
In Italy the forests that characterized the Apennine mountain areas were originally mixed beech and fir woods. Their composition and structure were simplified over the years due to the application of unsuitable treatments and uncontrolled grazing (Ciancio et al. 1985; Iovino and Menguzzato 1990). An analysis of some formations, selected in Calabria in one of the most significant areas from the forestry standpoint, made it possible to show how different selvicultural systems affect different somatic and chronological structures in the same types of forests.

2. Materials and methods

The study area (570.360 East; 4.223.560 North UTM-33) extends over more than 6300 hectares on the North-West slope of the Aspromontano massif. Most of the area is part of the Parco Nazionale dell'Aspromonte (Calabria, Italy).
The area's morphology is characterized by alternating flat and sloping zones. The mean gradient is 33% and the prevalent exposure is North-East. The lithological matrix comprises metamorphic rocks and alluvial deposits on the plains. The soils are Mediterranean brown and leached brown.
The climatic context falls into De Martonne's cold temperate climate with temperate and dry summers. From the phytoclimatic standpoint the area can be assigned to Pavari's cold *Castanetum* and warm *Fagetum*.
We studied the pure beech and mixed beech-fir woods that are situated between 900 and 1800 meters above sea level. The structural characterization was done through an analysis of the dendrometric parameters of the plants with DBH exceeding 2.5 cm in 19 transects measuring 10 x 50 meters.
The transects were scattered on the territory after the preliminary phase of interpreting black-and-white orthophotos taken in 1999 that were used to identify and delimit the various forest formations.
To calculate volume we used the volume tables constructed for the National Forest Inventory (I.S.A.F.A. – M.A.F., 1984).
The analyses made it possible to identify four different structural types: 1) monoplane beech woods; 2) biplane beech woods; 3) layered beech woods; 4) layered mixed beech-fir woods (FIGURE 1÷4).

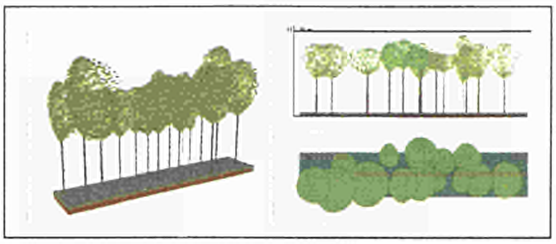

FIGURE 1- Monoplane beech woods

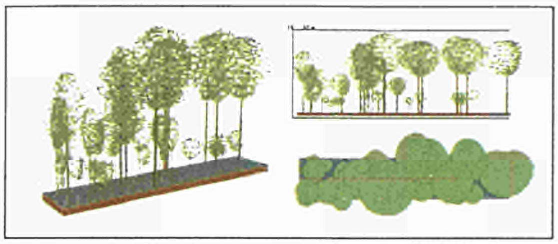

FIGURE 2 - Biplane beech woods

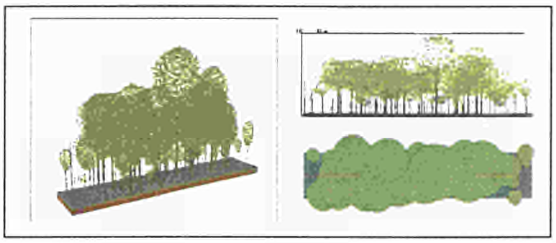

FIGURE 3 - Layered beech woods

FIGURE 4 - Layered mixed beech-fir woods

3. Results and discussions

The first type is the result of the application of shelterwood cuts with the chronological sequence of the classic schema; the second from the application of intensive seed cutting (50% of the basal area) and no final cutting. Both of these types are found primarily in the State property.

The pure beech and mixed beech-fir woods with layered profiles, on the other hand, are the result of selective cutting done mainly according to commercial criteria repeated at short intervals of about 7-10 years where large diameter plants were used almost exclusively. The two types are found primarily in the private property.

TABLE 1 – Main features and dendrometric parameters

Wood	*Structure*	*Surfaces* (ha)	*Surface %*	*Sample plots N°*	*Species*		*N° plants/ha*	*Quadratic mean diameter (cm)*	*Average heigt (m)*	*Basal area* (m^2/ha)	*Volume* (m^3/ha)
Pure	Monoplane	435	6.9%	6	Beech	***Mean***	***403***	***36.3***	***25.06***	***39.7***	***562.1***
						SD	135	5.8	1.63	7.7	126.6
						CV	34%	16%	7%	20%	23%
	Biplane	3590	56.9%	3	Beech	***Mean***	***600***	***25.7***	***22.00***	***31.0***	***427.0***
						SD	125	2.2	0.80	5.7	93.4
						CV	21%	9%	4%	18%	22%
	Layered	1035	16.4%	2	Beech	***Mean***	***1900***	***16.4***	***17.66***	***40.7***	***507.4***
						SD	396	1.4	0.80	15.0	232.1
						CV	21%	8%	5%	37%	46%
Mixed	Layered	1248	19.8%	8	Fir	***Mean***	***1300***	***23.0***	***17.94***	***40.1***	***444.2***
					+	SD	972	7.5	3.17	12	114.2
					Beech	CV	75%	33%	18%	30%	26%
					Fir	***Mean***	***731***	***22.9***	***16.38***	***25.9***	***258.6***
						SD	600	8.6	4.46	18.8	199.6
						CV	82%	38%	27%	73%	77%
					Beech	***Mean***	***569***	***20.8***	***19.51***	***14.2***	***185.6***
						SD	479	7.1	3.36	9.2	127.4
						CV	84%	34%	17%	65%	69%

Approximately 2/3 (64%) of the study area is characterized by plane-structural profiles, while the remaining 36% have layered profiles.

The most and least common structures are the pure biplane and monoplane beech woods that account for 56.9% and 6.9%, respectively (TABLE 1),

The analysis also highlighted the greater heterogeneity of the mixed forests with respect to the pure formations that is confirmed by the high coefficients of variation (CV) of the parameters studied (TABLE 1). Furthermore, if we evaluate the biometric parameters of the mixed formations separately we see a further increase in heterogeneity (TABLE 1).

In this context it is clear that the cultivation method will vary in relation to the structural situation under consideration and will be characterized by treatments that are diversified in time and space with the aim of increasing fir participation in the beech woods, increasing the structural complexity of the stand and thus improving the system's functionality.

Acknowledgements

This study was conducted within the context of the P.O.M. B28 – SISFOR Project – "New methods for the sustainable management of complex forest systems in Southern Italy" .

References

Agrimi, M.G., Ciancio, O., Portoghesi, L., Bozzoli, R. 1991. I querceti di cerro di Macchia Grande di Manziana: struttura, trattamento e gestione. Cellulosa e Carta 5:25-49.

Ciancio,O., Iovino, F., Menguzzato, G., Mirabella, A. 1985. L'abete (*Abies alba* Mill.) in Calabria: possibilità e limiti di diffusione e ridiffusione. Annali Istituto Sperimentale per la Selvicoltura, Arezzo,It, XVI:5-250.

Ciancio, O., Nocentini, S. 1994. La gestione forestale nelle aree protette. Linea Ecologica 6:10-13.

I.S.A.F.A.-M.A.F., 1984. Inventario Forestale Nazionale (I.F.N.I.). Tavole di cubatura a doppia entrata. Trento, IT.

Iovino, F., Menguzzato, G. 1990. Ecological factors and Silver Fir distribution in Southern Italy. *In* proceedings of the International Workshop-Mediterranean Firs-Adaptation, Selection and Silviculture, pp. 151-162. INRA-Avignon, 11-15 june 1190.

Monitoring technique and evaluation of damage due to *Altica quercetorum* Foudras (Coleoptera Chrysomelidae) in Sicilian deciduous oak woodlands

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Abstract
The damages on leaves of deciduous oaks due to the oak flea beetle Altica quercetorum Foudras was evaluated in four Sicilian woodlands by using a new monitoring technique. The percentage of damaged leaf area was assessed in the wood comparing the trees along two kinds of transects with standard photos of twigs bearing seven different measured infestation levels. The damage due to A. quercetorum resulted not homogeneous also analysing contiguous trees. At Ficuzza the average infestation level significantly increased from 1999 to 2000 (+ 3%), particularly on Quercus gussonei (+ 14%). In 2000 the infestation level was higher at Ficuzza (5 % of damaged leaf surface, from 800 to 1190 m a. s. l.) rather than in other woodlands of Sicani Mountains (1- 2% of damaged leaf surface). The infestation level was significantly higher: a) on the lower branches of the trees, followed by middle and upper parts respectively; b) at 601-700 m a. s. l., followed by 501-600, 701-800 and 801-900 m a. s. l..; c) on Q. gussonei rather than on Q. pubescens s.l.; d) in the inner part of the wood below 700 m a. s. l., while above this altitude it was higher in the outer part. Climatic data of the last 10 years suggest an influence of drier and warmer winters on the augmentation of the beetle population probably due to a lower mortality by the fungus Bauveria bassiana.

Keywords: defoliating insect, visual monitoring, *Quercus*, Sicani Mountains

1. INTRODUCTION

The oak flea beetle *Altica quercetorum* Foudras is a phytophagous insect mainly linked to deciduous oaks. Its damages on leaves due to the feeding activities of larvae and adults are still detectable in the beginning of Autumn, because this insect does not eat all the leaf blade, leaving nervations and upper or lower epidermis unaltered. It has one generation per year; larvae finish to feed in July, while new adults stop feeding in September (Mansilla et al. 1993). In the last years infestations of *A. quercetorum* have had a steep augmentation in Sicilian woodlands, especially at Ficuzza (Cavarretta D., personal communication). In this site a new visual monitoring technique was tested and a monitoring plan was carried out in 1999 and 2000; in the latter year also three other woodlands of Sicani Mountains have been monitored.

2. MATERIALS AND METHODS

The monitoring was carried out in October and November of each year, when the adult beetles already were in the overwintering places; at that time the undamaged leaf surface was still green.

Two kinds of transects were realised; the first one was realised going straight on, using a compass, from the border to the middle of the wood, monitoring a tree every 25 steps; the second one was realised along the roads bordering the wood, monitoring a tree every 100 m. The evaluation of the damage was made in the field comparing lower, middle and upper leaves of the oak tree with seven standard photos of twigs with different damage. The damaged and intact leaf surface of each photographed twig was measured by a Windias leaf area meter.

Infestation levels have been statistically analysed in relation to oak species, altitude, position of tree (i.e. interior or border of the wood), exposure of the slope. At Ficuzza, 17 transects inside the wood and 5 transects along the roads were covered, reaching a total of 11 and 8 km respectively, and an average no. of 568 oaks were monitored. During 2000, in the other sites of Sicani Mountains all the 5 transects covered 8 km, monitoring 113 oaks located from 850 to 1190 m a. s. l.

3. Results and Discussion

The application of this monitoring technique shows that the damage due to *A. quercetorum* is not homogeneous also analysing contiguous trees; further data collection using a little different technique could provide in the near future a good base to optimise the monitoring.

At Ficuzza the average infestation level significantly increased from 1999 to 2000 (+ 3%), particularly on *Quercus gussonei* (+ 14%)(Figs. 1-2).

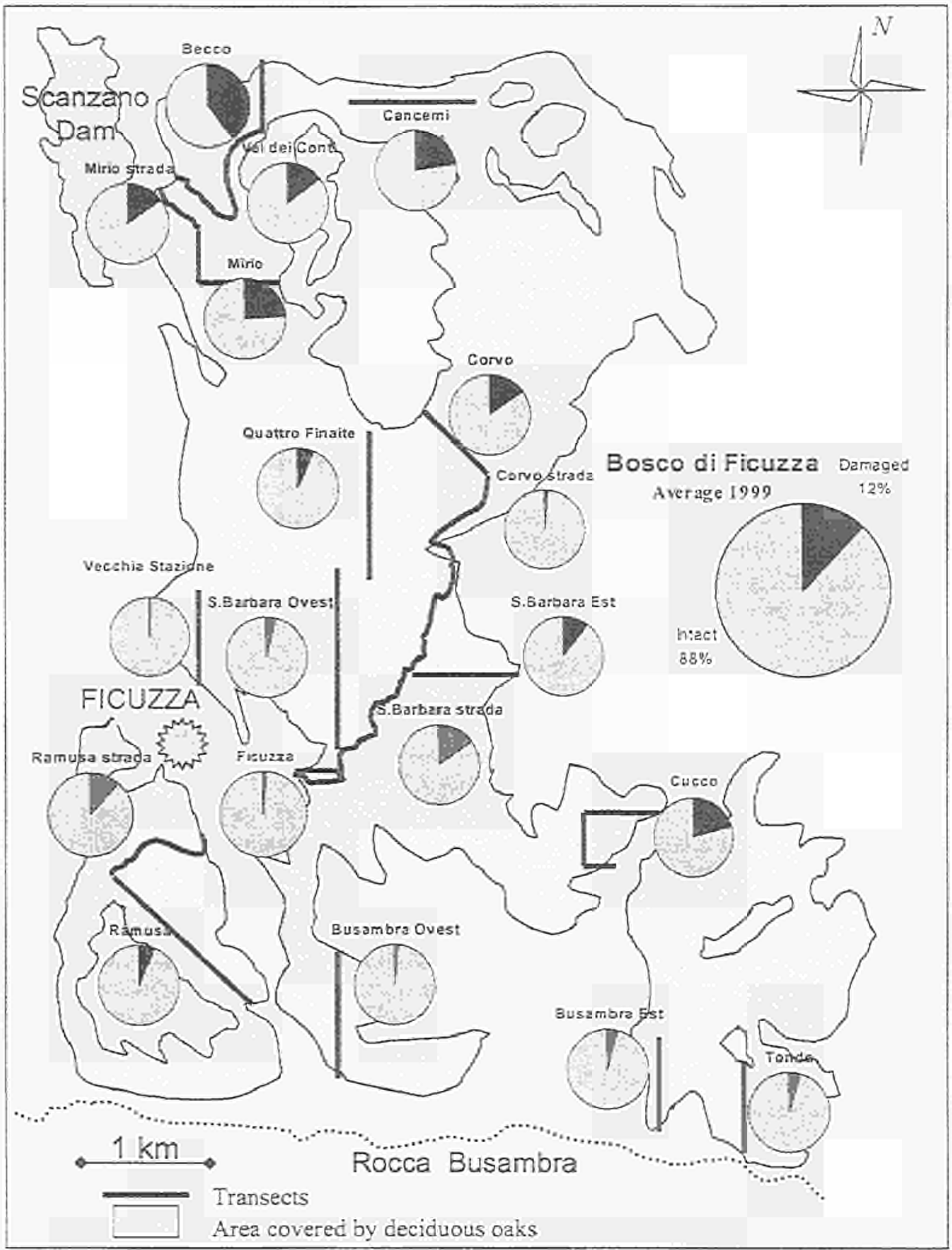

FIGURE 1 - Leaf surface of deciduous oaks damaged by *Altica quercetorum* at Ficuzza in 1999

In 2000 the infestation level was higher at Ficuzza (5 % of damaged leaf surface, from 800 to 1190 m a. s. l.) rather than in other woodlands of Sicani Mountains (Campofiorito 2%; Monte Carcaci 1%; Monte Genuardo 2%).
The infestation level was significantly higher:

a) on the lower branches of the trees, followed by middle and upper parts respectively;
b) at 601-700 m a. s. l., followed by 501-600, 701-800 and 801-900 m a. s. l.;
c) on *Q. gussonei* rather than on *Q. pubescens* s.l.;
d) in the inner part of the wood below 700 m a. s. l., while above this altitude it was higher in the outer part. This last finding implies that monitoring only along the roads is not enough to represent the infestation level.

Furthermore climatic data of the last 10 years suggest an influence of drier and warmer winters on the augmentation of the beetle population probably due to a lower mortality by the fungus *Bauveria bassiana*.

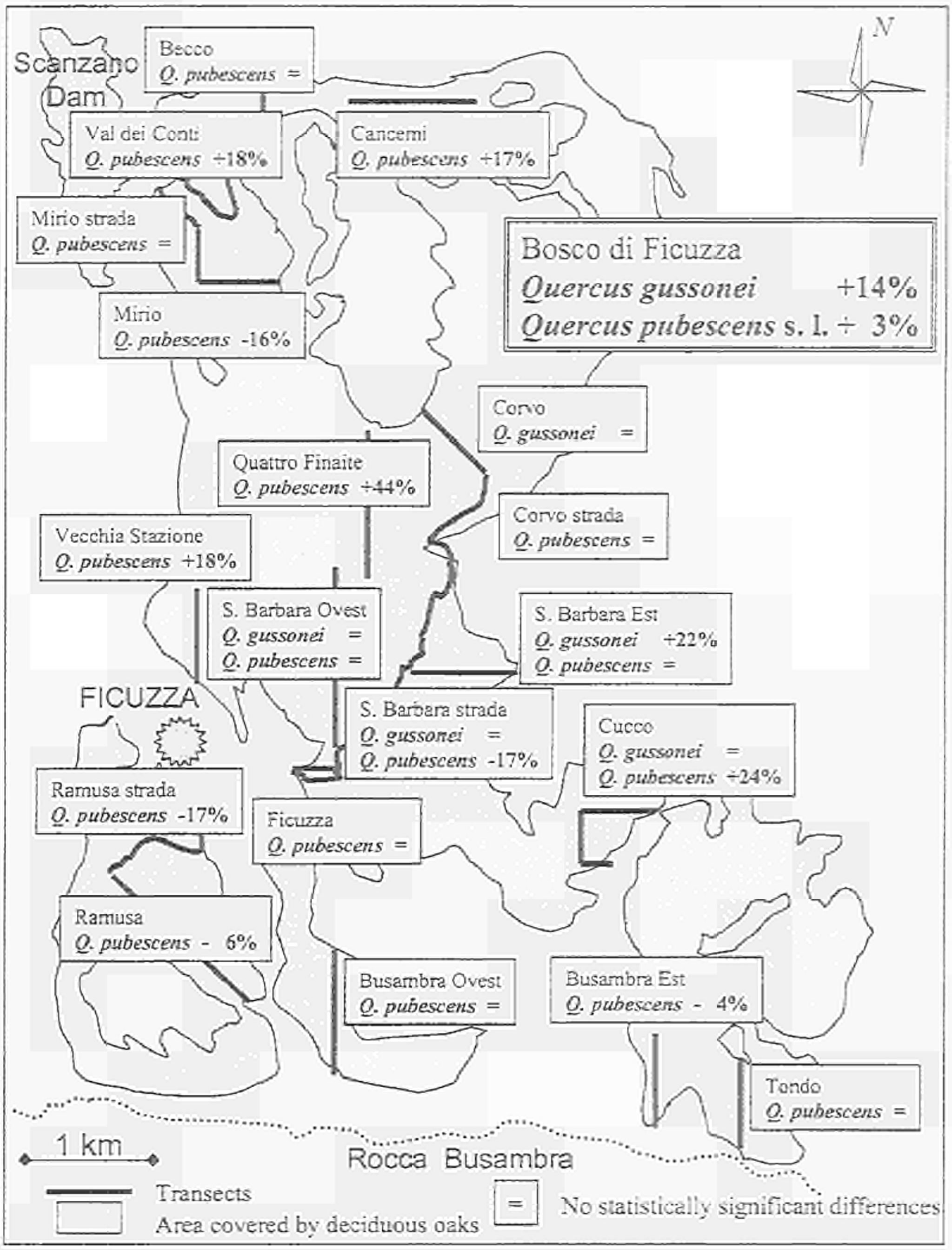

FIGURE 2 - Statistically significant variations in the leaf surface damaged by *Altica quercetorum* at Ficuzza from1999 to 2000

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REFERENCES

Mansilla, J.P., Iglesias, C. and Mazoy, D. 1993. Altica quercetorum Foudr. (Cole. Crysomelidae, Alticinae), plaga del roble en Galicia. Boletin de Sanidad Vegetal Plagas 19: 19-26.

Wildfire risk potential and expected impact analysis for sustainable forest management

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Abstract

The paper describes a proposed framework to identify the preparedness level required to effectively protect the forests from wildfires in a sustainable forest management perspective.
The preparedness level given within the designed framework results from the combination of the spatial distribution of estimated wildfire risk with the spatial distribution of expected impact of the same wildfires, i.e. the level of conflict between potential wildfires and the expected outcomes of natural resources. The work has been developed in the frame of the EU funded project Prometheus in which a number of knowledge based systems have been developed to estimate fire behaviour potential, fire effects to the ecosystems regeneration and resilience, post fire soil erosion and soil fertility.
In the paper presented, in order to provide an estimate of wildfire impact integrated in a forest management perspective, potential fire effects are scored according to their potential negative impact towards different possible forest management goals. The spatial distribution of wildfire expected impact combined with wildfire risk distribution provides an effective way to implement fire prevention plans consistent with forest management objectives. The method has been designed to be implemented in a knowledge based system applicable at local scale (i.e. province level), and has been partially tentatively applied in a study area of North-western Italy.

Keywords: wildfire risk, wildfire impact, fire management planning, forest management

1. Introduction

The work here presented is part of the research projects Prometheus and Prometheus s.v., funded by the European Commission, whose general aim is the development of knowledge based tools for the estimation of fire effects to forest ecosystems and to support organisation of fire prevention activities accordingly. Different knowledge engineering packages (KEPs) are included in Prometheus which are about fire prevention planning, fuel management, fire behaviour, fire suppression, fire effects to vegetation and ecosystems, fire effects to soil. Each KEP resulted into the development of a specific module of the Prometheus decision support system addressed to fire managers.
The purpose of the work here presented, is to illustrate the development of the fire prevention planning module, that deals with the allocation of fire protection resources and interventions in the territory based upon the analysis of protection priorities and their spatial distribution. The idea that is meant to be faced is that of a fire management planning framework in which fire management and forest management issues would be integrated. For this reason fire protection priorities have to be assessed not only according to the fire risk level but also considering the expected impact of potential wildfires on forest resource management together with the forest and land management goals.
The following paragraphs are meant to review some technical terms and to provide a general overview of the ideas that are behind the framework of the prevention planning module.
The wildland fire management terminology by FAO (1986) defines a fire management plan as a "statement, for a specific area, of fire policy and prescribed action" that "may include maps, charts, tables and statistical data" and the same definition is given in the Glossary of Wildland Fire Management Terms by McPherson et al. (1990).
Fire prevention applies to "all activities concerned with minimising the incidence of destructive fires", while incidentally, fire presuppression includes all the "activities undertaken in advance of fire occurrence to help ensure more effective fire suppression".
In general it could be stated that presuppression and prevention concepts include over-all planning but, more strictly, the activities involved in presuppression and prevention should be included in fire planning, which therefore in considered a more comprehensive concept. Note that in Australia, fire management plans are referred to as plans for organising prescribed fires in a region, as in Baird et al. (1994), but we will not consider this aspect.
Thus, the allocation of protection resources and interventions in the territory must be considered within the prevention tasks of a fire management plan and should be based upon the definition of protection priorities and their spatial distribution. The major outcome that is expected from the system is actually the preparedness level required, which is the operational expression of the protection priority in each geographical unit.
Fire prevention actions that can be considered are not only limited to the intervention undertaken onto environmental factors (e.g. decreasing fire hazard through fuel treatments) but also extended to prevention made improving the fire-fighting service capabilities (e.g. fire personnel training or organising first attack units).
Two main criteria are applied to define priorities, i.e. fire risk and expected impact, but in the analysis of fire risk it is embedded the evaluation of the effectiveness of the fire suppression organisation.

In addition to the mentioned criteria, forest and, more generally, land management goals must be taken into account and integrated into the analysis for the final assessment of priorities. In fact, once in a geographical unit a given fire risk level and expected fire impact on natural resources have been identified, a decision must be taken about the protection level that is required; such decision has to be taken also considering what are the general land management objectives in the geographical unit itself.
Implementing the ideas briefly illustrated into a decision support tool, that estimates the expected impact of forest fires and the fire risk level of individual geographical units crossed with general land management goals, and thus provides priority classification of the land to be protected, allows the assessment of expected results of alternative fire management actions and different forest and land management goals, and it is therefore the basis for integrating fire management plans into a sustainable forest management perspective.

2. Methods

The concepts previously illustrated have been formalised in a diagram, or knowledge tree, of fire prevention planning. The main components of the knowledge tree are depicted in Figure 1, and they will be briefly illustrated in the following sections.

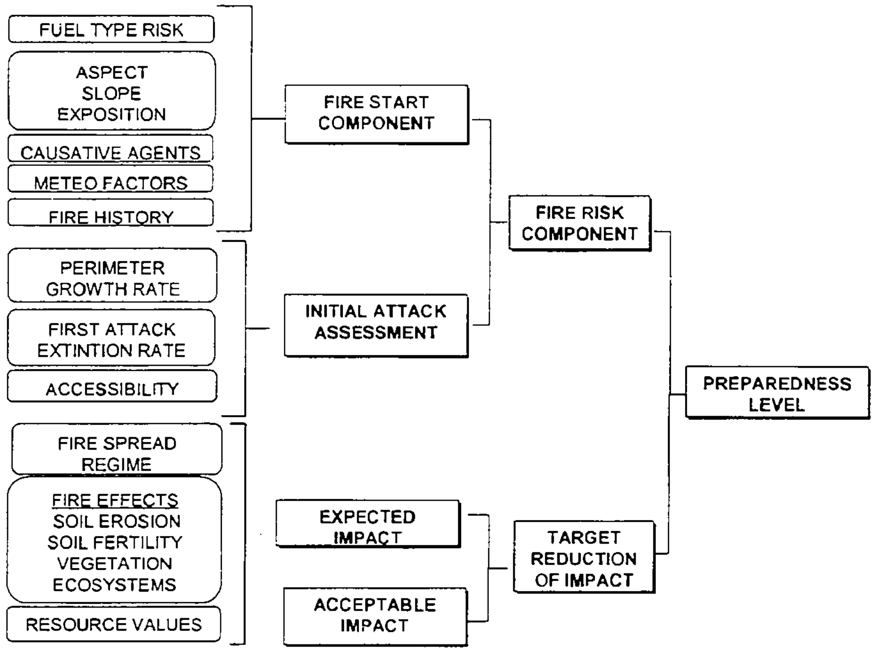

FIGURE 1 - Main components of the knowledge tree for forest fire prevention planning

The diagram is composed by parameters or components (see Figure 1), that are combined through functions (e.g. to combine the fire start component with the initial attack assessment parameter a specific function is used to give the fire risk component) that give as output new parameters that are combined using other functions until the root of the tree is reached, i.e. the preparedness level parameter.
A data dictionary of all parameters identified has been build with name, definition, classes, method of estimation and resolution of each parameter. For example the information contained in the data dictionary about the Fuel Type Risk parameter are the following:
Name: Fuel Type Risk
Definition: rating of the risk of eclosion and propagation of a given fuel complex.
Classes: 5 classes (very low, low, moderate, high, very high)
Definition of classes: the classes of the parameter are defined through their correspondence with Prometheus fuel types:

Classes		Prometheus fuel types	
1. Very low	:	1	(Agriculture)
2. Low	:	2, 6	(Ground fuels, Tree stand with clean ground surface)
3. Moderate	:	7	(Tree stand with medium surface fuels)
4. High	:	3	(Surface fuels)
5. Very high	:	4, 8	(Shrubs, Tree stand with heavy surface fuels)

Method of estimation: classification of fuel type map
Spatial resolution: cell size (50x50 m^2)
The functions used are of different kind, depending on the parameters: mathematical, statistical, rules. The rules, mostly of the if...then... type, have been set up using the methodology described in Eftichidis et al. (1994), namely following what is referred to as "induction methodology".

Fuzzy logical operators were also used to support function development during the analysis of parameters relationships, such as the following:

$$c = \mu \cdot MAX(a;b) + (1-\mu)MIN(a;b)$$

where c is the output parameter given by the combination of normalised values of parameters a and b, through a factor μ that is used to fuzzy the result between 0 and 1.

The estimates of parameters of interest is expected to be made for each geographical unit of the territory under protection. The estimation should be "static" with reference to a medium period, as we are looking for a way of classifying geographical units at planning level. Thus, parameters that are changing during time (e.g. meteorological ones) should be dealt with accordingly, as it will be explained later on. Also the spatial scales at which the parameters should be estimated can be different and this must be specified.

2.1 Fire Risk

The Fire Risk Component is defined as the risk posed by a fire, representing the possibility of having a fire that escapes initial attack and reaches undesirable size. Fire danger is a more comprehensive concept, including also aspect like fire behaviour and damage that may be caused by fires (FAO 1986).

These further aspects, although already partially included into the Fire Risk Component itself, have been included into the section of fire impact estimation that will be presented later.

Many efforts have been made to develop methods for estimating fire risk or fire danger levels and obtaining land classification tools useful for fire prevention purposes (Bovio and Camia 1994; Chou 1990; Chou et al. 1993; Chuvieco and Congalton 1989; Chuvieco and Salas 1996; Salazar 1990; Salazar and Palmer 1987; Velez 1994).

From a management point of view, in addition to the traditional topography, vegetation and weather factors, and besides the human factor which is the main cause of fire occurrence in the Mediterranean countries, it is important to take into account also the protection efforts that are actually undertaken in a given territory. These influence the level of fire risk with a negative sign, and it is especially useful to consider them, when the land classification that has to be made is meant to be a part of a Decision Support System for prevention planning as in the case of the work undertaken in the frame of Prometheus project.

Thus, the Fire Risk Component of the prevention planning diagram derives from the combination of the Fire Start Component (rate of probability of a fire to start) and the Initial Attack Assessment (probability of a fire being stopped by initial attack forces).

As it is well known, the factors influencing fire starting probability in a given area are basically given by the incidence of causative agents (mostly human), the fuel and its moisture content, the weather conditions.

The following parameters have been identified for appraising fire starting probability in a prevention planning context:

- Incidence of causative agents
- Fuel type Risk
- Aspect
- Fuel exposition
- Slope
- Weather factors
- Fire history

In what follows it is presented a brief description of the parameters selected and their role towards fire starting probability.

Causative agents cannot be dealt with in a generalised way, because in Europe they are mostly of human nature and are strictly dependent on socio-economical context. They should be specifically analysed in each situation, addressing a wider territory, to develop local predictors or find indicators of causative agents incidence. Therefore, in the first prototype of the system, causative agents have been simplified to a simple causative agents indicator which is generally recognised as having direct influence of fire occurrence, i.e. the distance from the roads and other land features such as parking areas and picnic areas.

In addition to causative agents, both the fuel complex characteristics and its average drought conditions over the season influence the ease of ignition. A number of site parameters have been selected in order to produce a local assessment of such factors. In the Fuel Type Risk parameter, fuels have been classified grouping fuel types used in the Prometheus system (Viegas et al. 1995) into classes of risk of eclosion given by the fuel complex properties.

Fuel moisture has been dealt with considering those site factors, mainly topographical, that influence the average drought conditions of ground fuels along the fire season. The parameters considered are Aspect, Fuel Exposition and Slope. Fuel exposition is defined as the exposition of the ground fuels to direct solar radiation as the consequence of the forest density. Slope is defined as the accounting of the slope effect on fuel drought due to the change in inclination of direct solar radiation.

Weather factors that affect fire occurrence changing over time, have been dealt with using average values and different expected scenarios during the fire season. With such approximation, weather variables can be considered reasonably homogeneous over areas of limited extension, also considering the fact that local topographic conditions are already taken into account in a different way.

Fire history is indeed very important because it gives a feedback information and because it can integrate the absence of factors influencing fire occurrence and that have not been taken into account. Nevertheless in most European situations historical fires are not mapped while it is simply recorded the administrative district in which each fire occurred. In such cases, for the analysis of the spatial distribution of historical fires, the resolution cannot go below the polygons of the administrative districts, which is in fact the resolution given to the Fire History parameter, that provides an estimate of the general level of wildfire occurrence over an area assessed through statistical data.
All the mentioned parameters concur to define in a given site and in a given season according to a specified scenario, a level of fire starting probability obtained by their combination.
To build the function that gives the Fire Start Component, the induction procedure described in Eftichidis et al. (1994), was followed. For each parameter a clear definition has been stated and a number of classes have been defined. After that, all possible combinations of classes of parameters have been considered, their relationships analysed and the expected outcome of each combination quoted, to finally produce a set of rules to be implemented in the decision support tool. The analysis was performed through separate estimates made by experts with reference to real situations, followed by discussions and comparison of results until a general agreement was obtained and the set of rules in the end defined.
To overcome the difficulties in handling a large number of parameters and provide consistent answers in all the numerous combinations, the problem was previously divided into subsets, considering the two reference scales at which the different parameters are referred to. In fact some parameters are local and concur to define "site specific" conditions and proness to fire occurrence, while other parameters should be dealt with at meso-scale level. Namely the latter parameters are weather factors and fire history, while causative agents incidence, even if can be considered in general also a meso-scale parameter, in the present case is basically a local one for the way it has been measured (distance from roads).
Concerning fire history, it must be underlined that it has to be considered over an area large enough to have a statistical representativity of fire data in the historical period considered, but with a limited extension to maintain sufficient internal homogeneity of the area itself (Bovio and Camia 1994).
Initial attack assessment is intended to give an indication of the chances for a fire being stopped by initial attack forces. The kind of initial attack considered is at this stage limited to fire fighters making direct attack on the fireline using individual (portable) equipment, that is a condition which is very often encountered in the European context. To considered a first attack successful, a burned area threshold has been defined at a fire size of 1 hectare, i.e. if the fire is contained below such area, the first attack is considered successful, otherwise the fire is considered escaped. In any case this threshold can be modified according to specific situations or planning goals.
The procedure that give its estimation make use of the following parameters:
1.Time needed for initial attack forces to reach the fire
2.Rate of increase of the fire
3.Extinction rate of the fire fighting crew
Therefore to assess the expected success of a first attack, as it has been defined, the parameters required are the time needed by the first attack to reach the fireline since the ignition that has resulted in a certain area burned, combined with the expected rate of fire increase and the productivity of fire suppression forces.
This has been solved for the prevention planing context, making reference to predefined fixed meteorological scenarios, to implement fire behaviour models and mathematical algorithms in order to combine estimated increase of the fire front, productivity of fire fighting crews and accessibility parameters.

2.2 Impact of forest fires

The impact of forest fires has been defined as the level of conflict between potential wildfire effects and the expected outcome of the resource threatened by wildfires (Bovio and Camia 1995). In this context the expected outcome identifies the value assigned to a resource that is threatened by the fire and it is therefore given by the Resource Value parameter in the Prevention Planning diagram.
The resource value is an expression of the social importance or function of the resource in the context of land management, in other words it refers to the goods and services that a resource is able to provide; for each function the fire impact has to be separately assessed.
Actually, two kind of resources have been identified that can be threatened by wildfires:

a. Urban resources, that can be damaged by a forest fire or can imply high risk for public health if burned. These are usually of little extension compared with forests where the fire takes place, so they can be considered as "sensitive points" (i. e. dots in the map) that can sometimes increase dramatically, but locally, the needs of protection. Examples are nuclear plants, military areas, communication plants, industrial plants, isolated houses, ancient places.
b. Natural resources, where and through which the fire propagates. An assessment of the economical value of the forests and the wild areas that could be burned by a fire could be requested to provide an estimation of the potential damage in these areas. This kind of evaluation can be very complex and costly. In addition the translation in economical terms of the several direct and indirect benefits that natural resources provide to society is also very difficult to achieve operationally. Therefore we have applied a simplified approach looking at the prevailing benefit that can drawn from a given resource (i.e. its main function) and evaluate the potential impact of wildfires towards that function.
The functions that have been considered are the following:

• timber production
• soil protection
• recreational use
• wildlife and livestock
• conservation of nature

In general it is basically a matter of land management and planning goals the attribution of the prevailing function to each geographical unit. The Expected Impact of forest fires parameter has then been defined as the assessment of the consequences of potential wildfires for land management. Thus the evaluation of the expected impact consists in identifying the level of the conflict between the potential wildfire effects on one side and each of the assessed expected outcomes of the natural resources on the other side (Figure 2). Fire spread regime must also be considered at this stage. The Resource Value parameter must therefore be crossed with the expected fire effects to soil, vegetation and ecosystems, namely Expected Erosion (EXER), Post Fire Nutrient Availability (POSF), Regeneration and Resilience (RGRS) parameters, and the Fire Spread Regime parameter (FSR).

Fire impact as well as all the parameters needed for its estimation (resource value, fire regime and fire effects) should be assessed for each geographical unit. The parameter values, that should be defined and combined in each unit, are estimated in a different way, each one being the output of other modules of the Prometheus System, outside the prevention planning module. The description of their methods of estimation is out of the scope of the work presented and will not be given here.

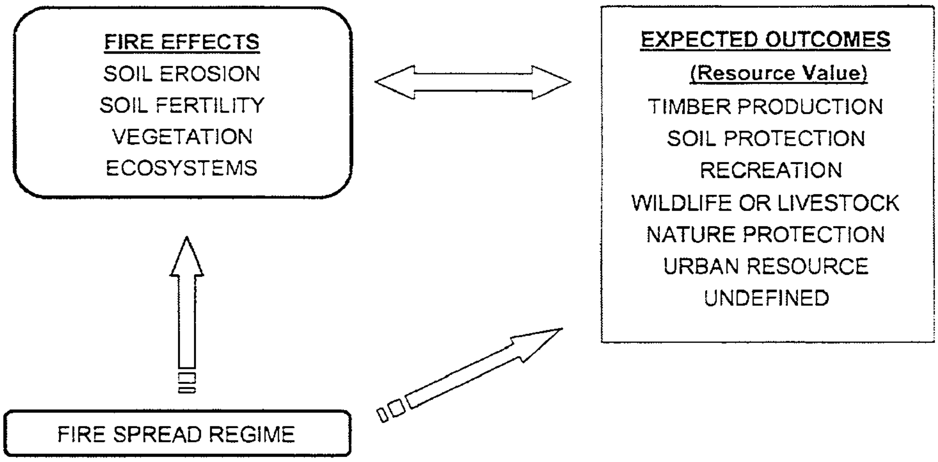

FIGURE 2 - Scheme that illustrate the parameters involved in the assessment of the expected impact of forest fires.

The conflict level between each expected outcome (function of the natural resource) and each one of the different mentioned parameters of fire regime and fire effects, should be finally combined with the following expression, in order to give a synthetic rating of the impact of potential wildfires on a given function:

$$I_f = 1 \cdot Max(a,b,c) + 0.15 \cdot Med(a,b,c) + 0.05 \cdot Min(a,b,c)$$

Where I_f is the expected fire impact on the function f from the combination of the partial impacts from the parameters a (RGRS), b (EXER, POSF) and c (FSR).

3. Results and discussion

The methodology developed has been partially applied to a study area of about 30,000 hectares located in Piemonte region, North-western Italy. The area has a range in altitude from 250 to 2600 m a.s.l., a forest vegetation cover mainly composed by broad-leaved stands. Some coniferous artificial stands are present, but covering a minor part of the area. Broad-leaved stands are represented mainly by coppice of *Castanea sativa* (around 7,000 ha), and mixed broad-leaved stands (around 5,000 ha).

3.1 Fire Risk

The parameters of the Prevention Planning diagram used for to the fire risk assessment were spatialised and therefore implemented in a GIS environment providing maps of the related output components. In Figure 3 it is illustrated the spatial distribution of the fire start component in the study area, showing a fairly good agreement with the superimposed spatial distribution of the number of forest fires occurred in a 10 years period.

3.2. Impact of forest fires

As mentioned in the previous section, the impact of forest fires assessment was dependent on analysis external to the prevention planning module, namely for those parameters related to estimation of expected fire effects. The methods to

estimate such parameters were initially developed on a fire event basis and they were found difficult to generalise in space. Therefore the impact of forest fires was not mapped but only the procedure for its assessment was defined.
The two parameters related to expected fire effects to soil, i.e. Soil Expected Erosion (EXER) and Post Fire Soil Fertility (POSF) were jointly analysed. That is, all possible combinations of the two parameter values (Table 1) were crossed with each value of the Resource Value parameter (RESV). The level of conflict corresponding to each cross combination of parameter values was rated between 1 (minimum) to 5 (maximum) and it is given in Table 1.
A similar evaluation table has been built with reference to the Regeneration and Resilience parameter (RGRS) crossing the 3 classes of RGRS with the resource functions and rating of the level of conflict (Table 2).
Also the Fire Spread Regime parameter (FSR) has been dealt with using an evaluation table crossing each of the 5 possible fire regimes with the functions of the resources threatened (Table 3).

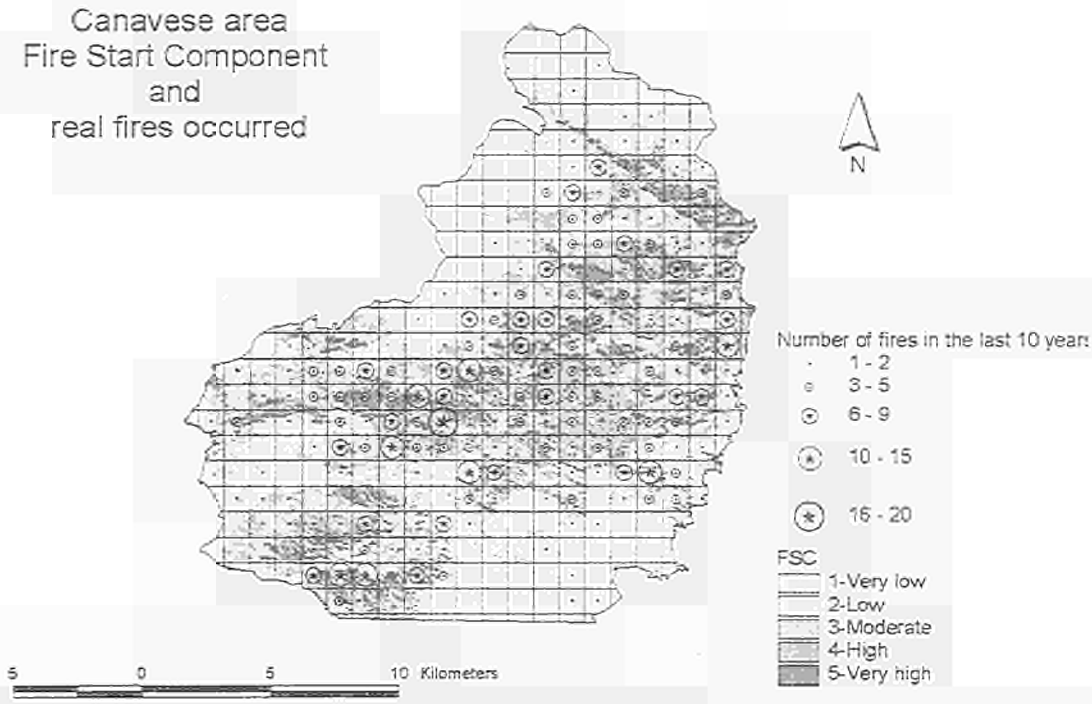

FIGURE 3 - Spatial distribution of the Fire Start Component (FSC) in the study area. FSC has 5 classes corresponding to the rate of probability of a fire to start.

TABLE 1 - Estimated level of conflict between each resource value (RESV) and the expected fire effects to soil (EXER and POSF)

EXER	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*	*Low*	*Medium*	*High*
POSF	*Positive*	*Positive*	*Positive*	*Negative*	*Negative*	*Negative*	*Uncertain*	*Uncertain*	*Uncertain*
RESV									
Urban res.	1	1	1	1	1	1	1	1	1
Timber prod.	1	1	3	2	3	5	1	2	4
Soil protection	1	3	5	2	4	5	2	4	5
Recreation	1	1	2	1	1	2	1	1	2
Wildlife	1	1	2	1	1	2	1	1	2
Nature protec.	1	2	3	2	3	4	2	3	4
Undefined	1	2	3	2	2	3	1	2	3

TABLE 2 - Estimated level of conflict between each resource value (RESV) and the expected fire effects to vegetation (Regeneration and Resilience parameter)

RESV	Regeneration and Resilience (RGRS)		
	Poor	*Moderate*	*Satisfactory*
Urban res.	1	1	1
Timber prod.	5	3	1
Soil protection	4	3	1
Recreation	4	2	1
Wildlife	5	3	1
Nature protection	5	3	1
Undefined	5	3	1

TABLE 3 - Estimated level of conflict between each resource value (RESV) and the expected fire spread regime

RESV	Fire Spread Regime (FSR)				
	Ground fire	*surf.fire 1*	*surf.fire 2*	*crown fire1*	*crown fire2*
Urban res.	1	2	2	4	4
Timber prod.	2	2	3	5	5
Soil protection	2	3	4	5	5
Recreation	1	2	3	5	5
Wildlife	2	2	3	4	4
Nature protection	2	3	4	5	5
Undefined	2	2	3	5	5

4. Conclusions

In a sustainable forest management perspective wildfire management goals and priorities must be closely connected with forest and natural resources management goals.

In this perspective, the concept of forest fire impact, defined as the level of conflict between potential wildfire effects and the expected outcome of the resource threatened by wildfires, has been introduced in Prometheus project for the first time.

The approach followed attempts the development of a decision support tool that combines fire risk assessment with expected fire impact and planning goals, therefore allowing the assessment of expected results of alternative fire management actions and different forest and land management objectives.

In the operational application of the methodology the main problems found have been in handling the spatial dimension of the expected fire effects to be crossed with the expected outcomes of natural resources to finally provide expected fire impact estimates.

Although the decision support tool was completely applied operationally, the prevention planning framework proposed provides a way to integrate, at local level, wildfire protection issues with forest management in the European environment.

Acknowledgements

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Notes

The work has been carried out in equal parts by the authors.

References

Bair, I.A., Catling, P.C., Ive J.R. 1994. Fire plans for Wildlife Management: a Decision Support System for Nadgee Nature Reserve, Australia, The International Journal of Wildland Fire 4(2): 107-121.

Bovio, G., Camia, A. 1994. Fire danger zoning using multivariate analysis. *In* Proc. 2nd International Conference Forest Fire research 733-745, Nov. 1994. Coimbra, Portugal.

Bovio, G., Camia, A. 1995. Criteria and Approaches to Fire Danger Zoning and Priority Zoning. Report of Prometheus Project, EC Project n. EV5V-CT94-0482, pp. 16.

Chou, Y.H. 1990. Modeling fire occurrence for wildland fire management: a GIS spatial analysis for fire control and prevention. *In* GIS/LIS '90 Proceedings Vol. 1, 440-449. Anaheim, California.

Chou, Y.H., Minnich, R.A., Chase, R.A. 1993. Mapping Probality of Fire Occurence in San Jacinto Mountains, California, USA. Environmental Management 17(1): 129-140.

Chuvieco, E., Congalton, R.G. 1989. Application of Remote Sensing and Geographic Information System to Forest Fire Hazard Mapping. Remote Sensing of Environment 29: 147-159.

Chuvieco, E., Salas, J. 1996. Mapping the spatial distribution of forest fire danger using G.I.S. International Journal of Geographic Information System 10(3): 333-345.

Eftichidis, G., Varela, V., Xanthopoulos, G. 1994. Using induction for developing expert system modules of forest fire management information systems. *In* Proc. 2nd International Conference Forest Fire research 123-130, Nov. 1994. Coimbra, Portugal.

FAO 1986. Wildland fire management terminology. Forestry Paper 70. Roma, pp. 257.

Mcpherson, G.R., Wade, D.D., Phillips, C.B. 1990. Glossary of Wildland Fire Management Terms Used in the United States. Society of American Forester: Washington D.C., pp. 138.

Salazar, L.A. 1990. Assigning Fire Management Analysis Zones with a Geographic Information System., International Conference Forest Fire research, B.16 - 1-11, Nov. 1990. Coimbra, Portugal.

Salazar, L.A., Palmer, K.E. 1987. Spatial analysis of fire behavior for fuel management decision marking., Poster paper at GIS '87. San Francisco.

Velez, R. 1994. Prévision du danger des incendies de forêt. *In* Proc. Course on Forest Fire Control 22-48, CIHEAM/ICONA/FAO. Zaragoza.

Viegas, D.X., Lopes, A.G., Viegas, M.T. 1995. Intermediate Report WP3 - Fire Behavior. Contribution of ADAI to the interim report of Prometheus Project, EC Project n. EV5V-CT94-0482, pp. 3.

GIS for monitoring of middle Siberia forests

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Abstract
A multilevel geographic information system (GIS) was developed for forest monitoring and ecosystem control of forest utilization. The system is based on remote sensing information and computer technologies. GIS technologies help to choose proper logging methods to apply to current stand state ecological forest use constraints, forest management strategy, etc.

Keywords: regional, subregional, local, database, images, GIS

1. INTRODUCTION

The Krasnoyarsk kray region occupies a huge territory stretching along the Yenisey river from the border of Tyva Republic at south to the Arctic Ocean at north within 52-81° N and 78-113° E with the length about 3400 km. In its widest part it is 1250 km and in the narrowest 410 km.
Such a long extent of Krasnoyarsk kray from the north to the south dictates the enormous variability in natural and climatic conditions and as a result variability in landscapes. The Kray crosses 5 natural zones: tundra, forest-tundra, taiga with northern, middle and southern taiga subzones, forest-steppe and steppe. Mountain vegetation is classified according to altitudinal zones: steppe, forest-steppe, taiga, subgoltsy, goltsy and mountain tundra. Altogether there are 152 types of landscapes across the territory of the Krasnoyarsk kray.
The Krasnoyarsk kray is very attractive for studying remote sensing methods in order to use them in solving problems of sustainable management under variable natural and climatic conditions, developed forest industry, regular large-scale natural and anthropogenic disturbances (pest outbreaks, fires, forest loggings). For example, as habitats of Siberian moth occur on areas with a high warmness index, distribution of landscapes with various thermal conditions should be taken into consideration when carrying out monitoring. It is necessary identify the location of landscapes-analogues in order to extend established regularities to similar territories. Such approach is used for landscape method of mapping.
The most actual tool for implementing of ecosystem control strategy is creating the system based on remote sensing information and computer technologies. The aim of activity is a creation of the multilevel GIS "Forests of Middle Siberia" for the purposes of forest monitoring and ecosystem control of forest utilization. The levels of forest monitoring, objectives, information base and data users are shown in flow-chat (fig. 1).

2. Methods

The regional level GIS is developed for the area of Middle Siberia (in borders of Krasnoyarsk kray for the total area of 2,4 million. sq. km). The system functional tasks are: monitoring the forest resources condition and their dynamics, planning forestry development; supplying information on biospheric forest functions to the researches.
The subregional level GIS is tested for the forest of the Lower Angara region (a cartographical trapezoid O-46). It is oriented to complex monitoring of a forest cover which is exposed to intensive anthropogenic pressure.
The local level GIS is developed for district forest management areas (FMA). Its main purpose is the information support of the ecosystem forest control and ecological certification of existing forest management systems. The GIS integrates forest management data, remote sensing information of high spatial resolution, field data of current changes in forests. The information is combined in common and thematic databases, forest utilization specification and ecological limitations. The users of Local GIS are: forestry experts, experts of the ecological technological processes in forestry woodsmans and lessees.

3. Results

Forest land classification with respect to insect activity levels was created using the computer overlay methodology for Siberian moth-affected areas, maps that show landscape structure, climatic conditions and forest species composition.
The analysis of the Krasnoyarsk kray forest dynamics has shown a remarkable decrease in conifer area over the past 30 years due to harvesting, fire, and insects, with a simultaneous increase in hardwood species. The area of young stands has been found to increase almost twice over this period of time.

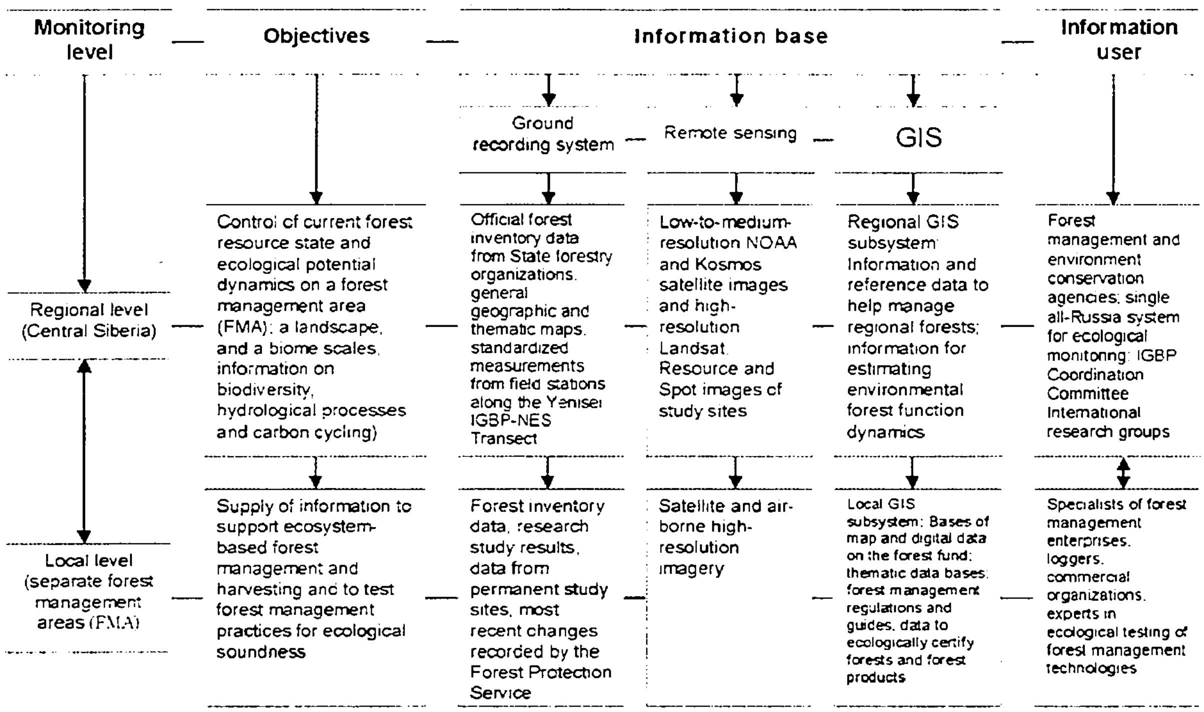

FIGURE 1. Central Siberian Forest Monitoring System Flow-Chat.

The analysis of ecology, landscapes and outbreak history of Siberian Moth allow to delineate 9 main districts of Siberian Moth outbreaks. The districts were ranged according to the following criteria: 1) the frequency of pest outbreaks (it varies within range from 2 to 10 per century); 2) the size of territory; 3) the "food" species (fir, pine or larch).

The analysis of insect "food" species base GIS technologies (which exclude felling for the territories with not favorable climatic conditions e.g., high altitude zone), is important for creating of operative maps for potential outbreaks areas.

Local GIS-based monitoring is tested in some separate forest management areas. For the given area, GIS contains large-scale vegetation maps linked to the forest inventories database. The cartographical data spatially put on a digital elevation model, that allows determining an altitude, aspect, slope and different relief plastics indices for a given area.

We estimate current stats of forests and their ecological role from statistical analysis of stand inventory and morphological characteristics, with its results being presented in a plotted or digital form.

Using the database of the forest fund, forest fuel maps are built. Based on these maps combined with current weather forecasts, we develop operational forest fire danger maps, which are used by fire protection personnel in ground fire patrol.

GIS technologies appear to be very helpful in choosing proper logging methods with respect to site conditions, current stand state, and ecological forest use constraints. Management activities in the form of improvement logging is a complicated ecological and economic system resulting from a great variety of ecological conditions and adequate ecosystems, as well as social and economic situations, in which forest management is carried out. Practical activities in forest growing, improvement loggings, final loggings become impossible without justified regulations and principles of intervention into forest ecosystems providing their regeneration and ecological safety of landscapes where these ecosystems function.

The analysis of the expert and GIS data let us formulate primary conclusions:

1. Contribution of Siberian stone pine (*Pinus sibirica*) stands to the total forested area of Forest Management Unit is not large but they are of great importance as resources of valuable timber as well as nuts which are food not only for local population but also for wildlife. Deciduous-Siberian stone pine secondary stands and stands with Siberian stone pines occurred in the composition are of primary importance when using improvement loggings in order to form early and intensively fruit-productive trees of Siberian stone pine.

2. The most valuable commercial species in the Forest management Unit is pine (*Pinus Silvestris*) and as a result pine stands are subject to logging to the biggest extent. Portion of relatively young pine stands covering 7.8% of forested area at the age when improvement loggings are conducted increased 1.5 times to 11.8%. These stands are immediate aims for improvement loggings.

3. Fir and spruce stands and mixed stands with a low portion of fir and spruce are to be covered with improvement logging in case they grow under favourable site conditions aiming at forming highly productive stands with timber of high quality.

4. Among the stands at the age when improvement loggings are conducted (1-4 age class) contribution of deciduous species is large (birch - 32.4%, aspen - 13.9%) and accounts for 46.3%.

It is obvious, that improvement loggings will not be prescribed to all birch and aspen stands. In this category of young stands, coniferous species are of prime importance which are overgrown by deciduous species in mixed stands with admixture of conifers in composition (or in one story) and multilayer stands with conifers.
The forest sylvicultures database is constructed in the same way on the basis of forest inventory database and information about current forest fund changes fixed annually in FMA both as by field examinations, and with data decoded from aerial photographs of large and middle scales, and also with the help of available satellite image analysis.
There are vast areas in the taiga zone of Siberia. This areas need artificial reforestation and make up a forest cultural fund (FCF), owing to constant anthropogenic effect (fires, loggings) and outbreakes of pest number (especially Siberian moth). The task of getting an information on this area, including its transport and economical accessibility is possible only using remote sensing data and methods of sustainable forest management based on GIS. The principles of obtaining necessary information were developed to solve this problem. They can be briefly formulated in the following:
1. Data bank on FCF is formed on the base of materials of forest organization taking into account current changes in the forest fund. These changes are annually registered in the leskhos both by ground-based investigations and by decoding airborne large- or middle-scaled images as well as by methods of result analysis of accessible photographic and scanner space survey.
2. Material analysis according to FCF assessing in different regions of the Krasnoyarsk Kray region allowed to distinguish its main categories: wastelands, openings, burnt areas, felled areas, destructed tree stands (by Siberian moth) without satisfactory regeneration of the main tree species, forest sylvicultures with unsatisfactory quality and dead ones, areas which need reconstructions.
3. It is reasonable to form integral quantitative characteristics of FCF status according to forest districts with assessing areas, groups of forest types, tree species and total clutterring.
4. Prompt information on spatial distribution of FCF in the form of electronic maps allows to estimate the transport and economic accessibility as well as to determine a succession of its efficient exploiting. Couple analysis of spatial information on tree stand distribution according to prevailing tree species, site quality classes, stand age, forest types, moisture and mechanical soil structure, slope steepness and aspect (obtained by a digital elevation model) will allow to solve the problem of selecting optimal regimes of growing site of particular forest sylvicultures and to localize more exactly their planting on the territory.
Forest productivity losses due to fire, logging, and insects are determined for a range of site conditions based on the GIS digital information analysis. The biggest (up to 60 percent) losses have been found for pine stands that experience intensive logging and fire. The results are available in the form of computer maps showing productivity process disturbances.
In order to actualize the information in the GIS database the image processing methods are used for satellite images of SPOT, Landsat TM and «Resource O1-3» systems. The satellite images are used to define forest species and types, vegetation conditions and biomass values estimation, and also location of areas with different degree of stand damage made by the Gypsy moth.

Probability fuzzy mapping of forest disease in central Italy

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Abstract
The project TRANSITALIA has been developed in selected test sites in Central Italy to map forest health conditions and forest types on the basis of Colour Infrared aerial photography. In this paper the area of Abruzzo region has been adopted to test a methodology voted to use mapped information, namely those acquired in TRANSITALIA project, to infer about forest health conditions in the whole forest area of Abruzzo.
Different approaches have been tested and the selected one is based on the integration of CORINE Land Cover and TRANSITALIA data sets, supported by ancillary information, with a fuzzy Multi Criteria Evaluation (MCE) process. On the basis of statistical tests, TRANSITALIA geographical dataset has been judged as a good representative sample of Corine Land Cover map. On this basic hypothesis and using spatial auxiliary information, the distribution of potential forest disease condition has been modelled in a GIS environment. The result is a fuzzy map of forest stands vulnerability level in Abruzzo region. A cross tabulation analysis has been used to verify the accuracy of achieved results.

Keywords: **forest damage, fuzzy analysis, multi criteria evaluation, forest type, CIR photos for forest mapping**

1. Introduction

Present work deals with a methodological approach to combine existing geographical datasets acquired with different aims and procedures on the same area to produce a potential vulnerability map of forests in central Italy. The regional forest administration of Abruzzo required and financed the project in order to obtain a geographical dataset to support its institutional activity in forest management over large areas. Achieved results of such a first modelling experience can be used to improve the knowledge of forest ecosystems in central Italy and to better understand their vulnerability to changing environmental conditions.
The project TRANSITALIA (Marchetti et al. 1999) was developed in 1997 in selected test sites in Central and Southern Italy in the context of EU Regulations on Protection of Forest Health and Vitality, to map forest health conditions and forest types on the basis of Infrared False Colour (CIR) aerial photographs. The entire area of Abruzzo region covers over 10837 km^2 (see Figure 1) and it has been used to test a methodology to use mapped information acquired in TRANSITALIA project to infer potential vulnerability of Abruzzo forests; the approach aims to integrate CORINE Land Cover and TRANSITALIA data sets, supported by auxiliary information, with a fuzzy Multi Criteria Evaluation (MCE) process. Most of MCE analysis methods (such as fuzzy sets theory, evidential reasoning or neural networks) are based on *a-priori* user defined information regarding the relationship between the studied phenomenon and a variety of multisource information input data layers (Peddle and Ferguson 2002). The present work deals with the possibility to acquire information regarding relationships between environmental parameters in few and small study areas and to replicate and expand them in a larger geographical context. The application is a first tentative approach to address the increasing needs for more complex information extraction in the Environmental and Earth Sciences (Jensen 1996; Burrough and McDonnell 1998).
This work could also be interpreted as a first step, based on a GIS approach, to better understand the relative influence and importance of different environmental factors in determining forest health conditions. Such spatial information could be useful to discriminate the relative impact of other biotic and abiotic factors on forest environments (Thomsen and Nellemann 1994).

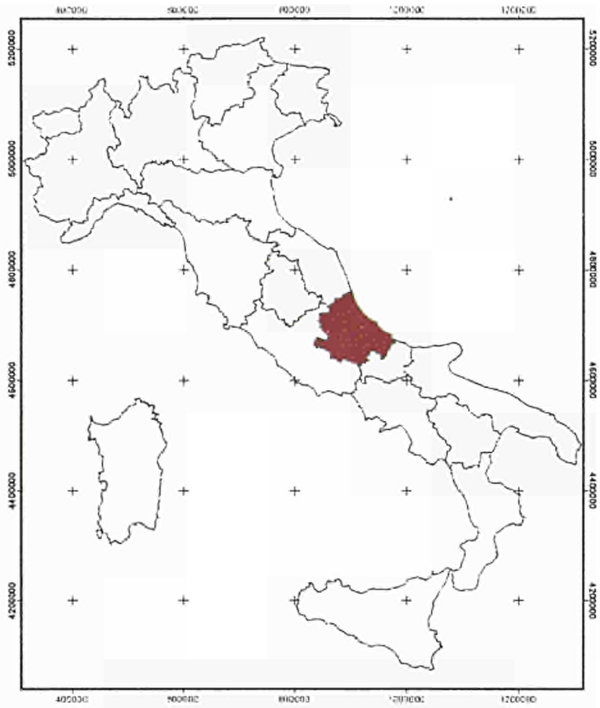

FIGURE 1: location of Abruzzo region.

2. Materials and methods

The final goals of TRANSITALIA project are: to create a Forest Types Map and to elaborate a Forest Disease Map, both at a 1:25000 scale. The methodology is based on the interpretation of CIR aerial photos (average scale 1:20000) covering more then 1200 km of strips of a specific flight. The use of CIR photos is consolidate in the literature and is currently adopted in many national forest inventories and damage assessment studies (Marchetti and Castagnoli 1989a,b; Marchetti and Buffoni 1994; Marchetti et al. 1997; Marchetti and Gomarasca 1998). The area covered by TRANSITALIA project was chosen to cover some of the most important forests in the central and southern Italy, all over the Appennini mountains.

Photo's strips are 10 to 70 km long and around 4.5 km wide; the aerial survey was made during summer 1997.

The result of the interpretation of the photos was digitised on the basis of topographic maps 1:25.000 produced by IGM – Istituto Geografico Militare (Geographic Institute of Italian Army).

The forest map was completed reporting in each polygon data on forest species composition, vertical structure and density. On this basis the photos were analysed to detect forest health conditions. A systematic grid of 0.5 cm (around 100 m on the ground) was superimposed on the photos and for each point it was evaluated the health status of tree canopy, on the basis of species specific damage keys and procedures reported in the manual "Remote Sensing Applications for Forest Health Status Assessment" (EC, 1991).

The photo interpretation of forest health status, as point data, was then spatially joined with the forest map 1:25.000 previously carried out, to calculate the average condition of each forest patch. In some cases, when the variability of health data in a single patch was too high, the polygon was splitted.

In the Abruzzo region the TRANSITALIA dataset covers three sites for a total of 23888 hectares of forests (see Figure 2).

Besides TRANSITALIA, in 1998 the Italian Ministry of Environment funded a project to map vegetation coverage in Italy upgrading the official Corine Land Cover dataset with a 4th thematic level in the nomenclature (Corine LC4). The project is based on computer assisted interpretation of multitemporal Landsat 5 TM images (acquired between 1995 and 1996) integrated with ancillary information (Digital Elevation Model, existing vegetation maps, etc.). The scale of the project is 1:250.000. On this basis the forest area of Abruzzo is over 588000 ha (see Figure 3). The datasets used in the present work is completed by a Digital Elevation Model (DEM) with 75 m resolution available in Italy at national level.

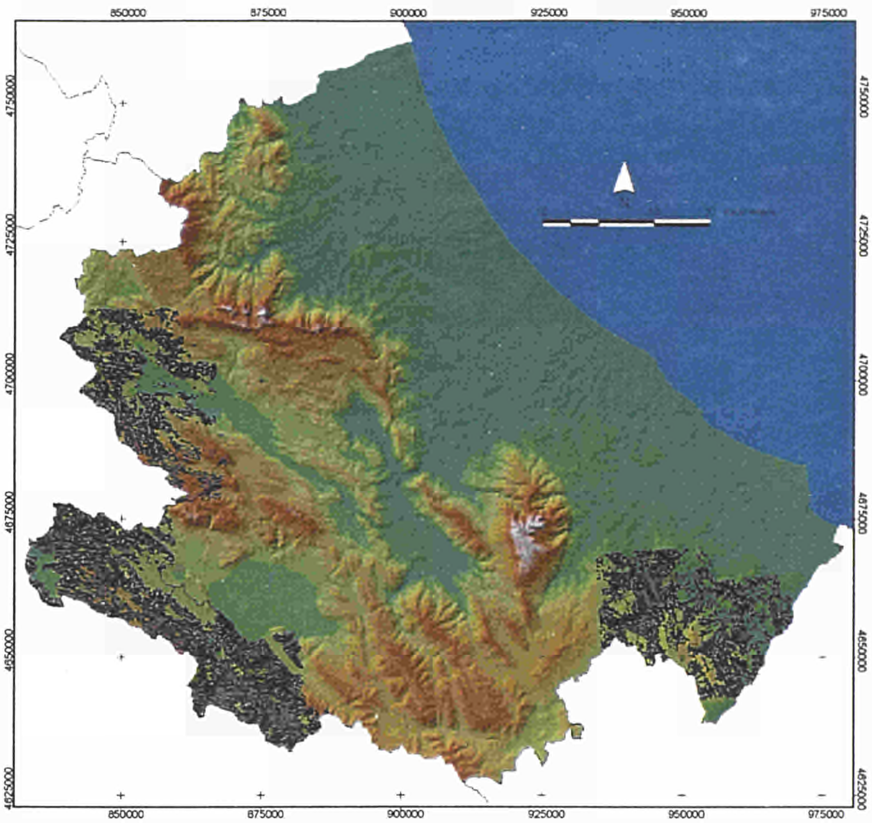

FIGURE 2: Digital Elevation Model of Abruzzo region. Vector layers show the location of test areas mapped in the project TRANSITALIA.

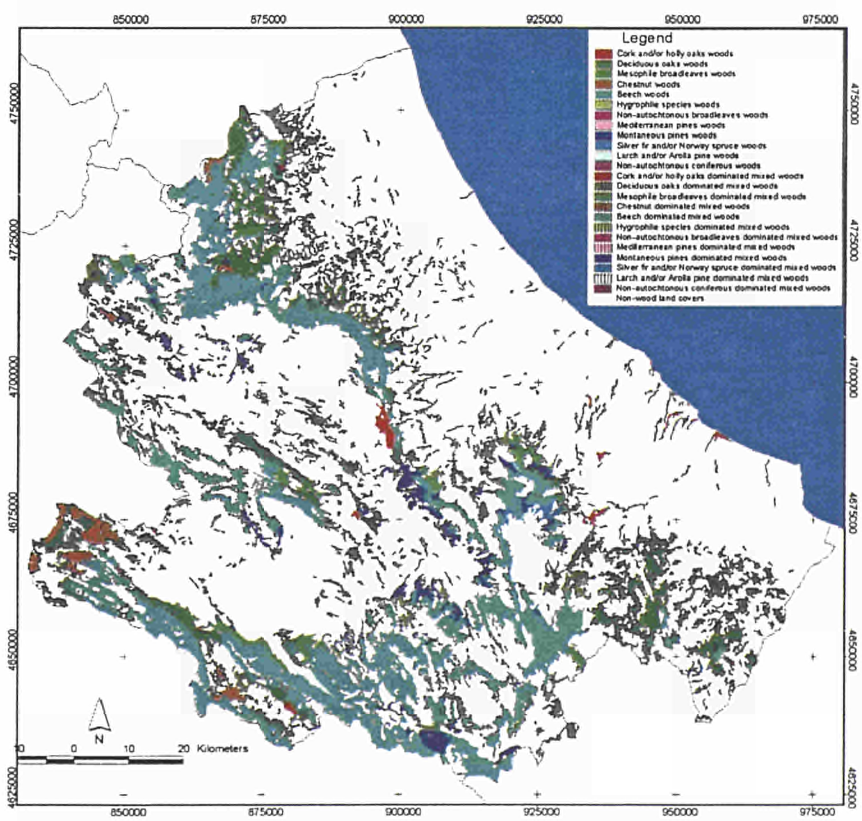

FIGURE 3: Corine LC4 forest classification of Abruzzo region.

The first part of the work deals with the evaluation of congruency between Corine LC4 and TRANSITALIA datasets. The coverages have been transformed in raster format with the same resolution of DEM and resampled in the same geographic system (UTM on the European datum 1950).

Forest definition in both the projects is quite similar. Comparing boolean forest-non forest maps derived from original datasets we got a KIA (Kappa Index of Agreement) of 0.89.
The Corine LC4 dataset is structured in a 24 forest classes system of nomenclature while the TRANSITALIA forest types map was based on 29 forest classes. Even if both the systems are very detailed, the forest classification approaches are different. After a re-classification process a final 9 classes system was arranged and it can be considered as the most detailed nomenclature system common to both the projects.

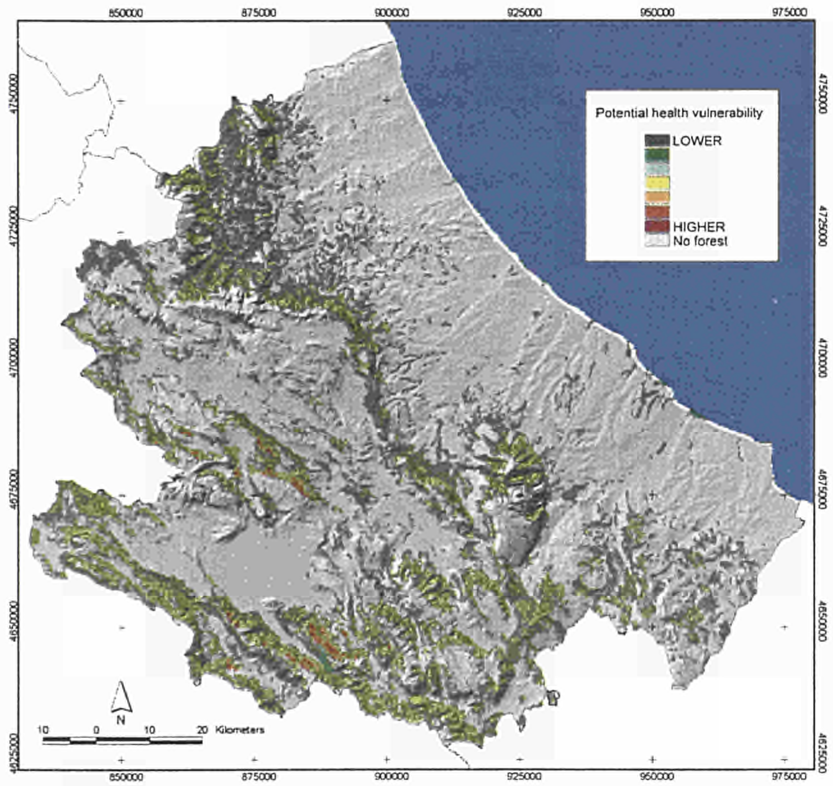

FIGURE 4: potential health vulnerability map of Abruzzo region.

To model potential forest health vulnerability of Corine LC4 forest patches on the basis of TRANSITALIA health condition maps, forest area interested by TRANSITALIA project had to be considered as a representative sample of global environmental conditions of all forests in the region. To verify such hypothesis the distributions of four factors (altitude, aspect, slope and distance from the sea) have been calculated both for the regional forest area and for the forest area mapped by TRANSITALIA project. While three factors have the same kind of distribution in both the datasets, the fourth one (distance from the sea) has been discharged because the area investigated in TRANSITALIA project is located just in the internal part of the region.
The implemented model is based on a frequency to probability transformation. The model simply replicate the same distribution of forest health condition against available environmental parameters for an area wider then the original one where data were acquired. Once demonstrated that forested area analyzed in TRANSITALIA project is a representative sample of all regional forests, the distribution of health disease (considering four main factors: forest species, elevation, slope and aspect) observed in the TRANSITALIA dataset was replicated for the Corine LC4 coverage. For instance, the more frequently a stress status is observed for a specific combination of forest type, elevation and aspect, and the higher potential health vulnerability will be predicted for such conditions in all the regional forest area. TRANSITALIA dataset could therefore be considered something like a list of training sites useful to evaluated potential health vulnerability of forested area in Abruzzo.
The adopted procedure operatively proceeded from the 9 classes common legend, deriving four models : one for *beech forests,* one for *deciduous oak forests*, one for *chestnut forests* and one considering *all forest categories* together. Each model was based on three factors: elevation, aspect and slope.
TRANSITALIA dataset has been randomly splitted in test sites (used for accuracy evaluation of model results) and training sites (used for model development).
The averaged health condition has been calculated from TRANSITALIA dataset for each elevation class (100 m classes from DEM), for each aspect class (9 classes from aspect map: 8 directions plus one for flat areas) and for each slope class (10% classes from slope map).
CORINE LC4 map, reclassified on the basis of the 9 classes common system of nomenclature, has been used to stratify the regional forested area on the basis of the forest types defined for modelling. Areas falling in one of the specific forest classes were modelled separately, the others were instead elaborated with general information for all forests.

For each forested pixel of Corine LC4 map a fuzzy value (between 0 and 1) of potential health vulnerability has been calculated considering its forest category, altitude, aspect and slope. Formally:

$$index = \sum_{i=1}^{n} \sum_{j=1}^{m} P_{ij} \text{ where:}$$

i is the forest category considered (beech, oak, chestnut and global);
j is the ecological factor considered (elevation, slope and aspect),
P is the normalised averaged health condition derived from TRANSITALIA dataset in considered forest type and for the specific environmental condition.
index is the fuzzy potential health vulnerability of the pixel.
Test sites from TRANSITALIA have been used to evaluate how the predicted potential health vulnerability of forests is related with actual health condition of stands (Figure 5).

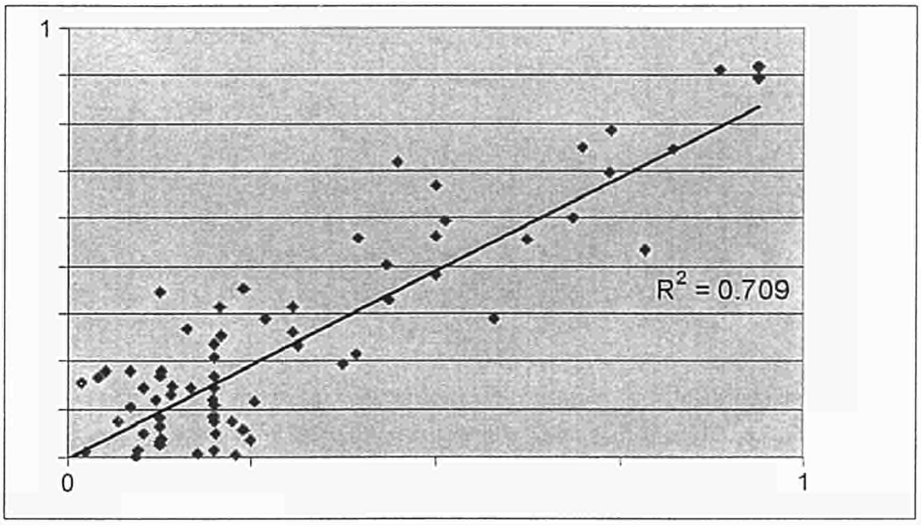

FIGURE 5: statistical linear regression between predicted potential health vulnerability (x axis) and real measured health condition (y axis). From 0 to 1 increasing health disease and vulnerability. Number of test sites: 850.

3. Results

The environmental factors used to model the potential health condition of forests in the whole study area seem to explain most part of the spatial variability of studied phenomena at a regional scale. The statistical regression between potential vulnerability obtained with the proposed methodology and health conditions mapped in TRANSITALIA project shows a good relationship, R^2 close to 0.71 (Figure 5).
Climatic conditions seem to be the most influent factors. Areas at higher elevations and aspects fronting the Adriatic sea (N-NE) have a significantly higher number of forest stands with clorosis and defoliation phenomena. Probably, the strong winds from such direction, winter snowfalls and out-season frozens significantly contribute to the health status of Abruzzo forests that, anyway, are globally in good condition.
The spatial distribution of the potential health vulnerability values is reported in Figure 4.
In Figure 5 it is graphically shown the accuracy evaluation of the model obtained by linear regression between modelled health vulnerability values and mapped health condition as reported in the TRANSITALIA project.
It is of course possible to reclassify fuzzy continuous data of potential vulnerability into many different discrete classes. Using a simple linear division of the original interval 0 – 1 in three classes (the first one between 0 and 0.33, the second between 0.33 and 0.66 and the last one between 0.66 and 1) a crisp map was finally produced. The 97.5% of forests (more then 322000 ha) is environmentally quite far away from those conditions were more frequently the TRANSITALIA project has highlighted crown stress conditions. The second and third classes represents respectively 2.3% (more then 7500 ha) and 0.2% (752 ha) of total regional forests and represent stands with higher potential vulnerability. The most part of them are localised at the top of mountains fronting the sea.

4. Conclusions

The proposed method is an experimental test to evaluate how different environmental datasets with different reference scales and different nomenclature systems, acquired with different aims and methodologies, could be integrated in a GIS environment to produce useful multiscale spatial information supporting sustainable forest management choices.
The methodology simply replicates an environmental phenomenon as it happens in the surroundings of the area where original field data were acquired without requiring any user defined inputs which can be difficult to provide (Peddle and

Ferguson 2002). The basic modelling requirement is that both the two areas must have similar conditions for all the environmental parameters involved in the simulation.
In this research, on the basis of the produced map (Figure 4), it is possible to localise those forest stands that are in the same ecological conditions of forest stands where health status has been found worst during the TRANSITALIA monitoring project. In other words, the information produced could be considered also as an ecological proxy measurement to that conditions where more frequently forest disease phenomena were detected. When a forest stand has environmental conditions similar to those ones of damaged stands mapped in TRANSITALIA (in terms of dominant forest species, aspect, altitude and slope)its level of potential vulnerability is higher and vice-versa.
Such kind of information can be used by forest services and decision makers for different purposes. First of all it is important to deeply investigate the phenomenon to better understand if the predicted value has a real value also outside the surveyed test areas. Also, monitoring networks could be better and more efficiently designed with such information layer; for example, different grid densities could be designed in relationship with the results of modelled potential forest health condition.
Model results should also deeply investigated to better understand the relative influence of analysed environmental conditions (Webster et al. 1996; Huston 1997) and other important parameters that are demonstrated to be important for forest health status (Nevalainen and Yli-Kojola 2000): like sea-salt injuries (Aamlid 1995), climatic conditions (Solantie 1994), air pollution (Aamlid et al. 2000) or other abiotic factors (McKay 1988). Few practical indications could anyway help in operating such kind of GIS overlay analysis. The most important regards the definition of the classification target before the beginning of a forest monitoring program, especially if it is based on remotely sensed data. Different efforts at national, European and global level have nowadays their main target in developing a common definition of forest (Nemani and Running 1996) within a multi-scalar system of nomenclature (Corona et al., in press). If monitoring target requires a specific legend, the relationship with common reference systems should be anyway clearly and uniquely defined before the beginning of the project itself.
We therefore hope that the development of an harmonized national system of nomenclature integrated with international standards and the implementation of a national forest information system, could help in the future for the definition of land management policies closer to the principles of sustainable development and *close to nature* silviculture.

Notes

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References

Aamlid, D. 1995. Sea-salt injuries to conifers along the western coast of Norway. *In* Forest Pathology Research in the Nordic Countries 1994, pp. 68-71. Proceedings from the SNS-meeting on forest pathology at Skogbrukets Kurssenter, Biri, Norway 9±12, August 1994. Edited by Aamlid, D. Aktuelt fra Skogforsk 4-95.

Aamlid, D., Tørseth, K., Venn, K., Stuanes, A.O., Solberg, S., Hylen, G., Christophersen, N., Framstad, E. 2000. Changes of forest health in Norvegian boreal forests during 15 years. Forest ecology and management, 127: 103-118.

Burrough, P.A., McDonnel, R.A. 1998. Principles of Geographical Information Systems, 2nd edn. Oxford University Press: Oxford, pp: 333.

European Commision 1991. Remote Sensing Applications for Forest Health Status Assessment. Luxembourg, pp: 238.

Houston, D.R. 1987. Forest tree declines of past and present: current understanding. Can. J. Plant Pathol. 9: 349-360.

ICP (United Nations/European Union) 1996. Forest condition in Europe. Report on the 1995 survey. Geneva, Brussels: UN/ECE, CEC.

Jensen, J.R. 1996. Introductory digital image processing, 2nd edition. Prentice-Hall, Upper Saddle River, NJ, 316 pp.

Marchetti, M. and Castagnoli, A. 1989a. Proposed methods for application of new techniques for vegetation inventory, forest damage evaluation, their cartographic representation and permanent monitoring. Proceedings of Int. Conference on "Global Natural Resources Monitoring and Assesment: preparation for the 21st century", FAO-IUFRO, Venezia, 1989: 496-503.

Marchetti, M. and Castagnoli, A. (edts) 1989b. Se il bosco muore. Ed. Compagnia Generale Riprese aeree, Parma, 1989, pp.1-141.

Marchetti, M. and Buffoni, A. 1994. Application of photogrammetric methods for forest mapping and surveying: preliminary results of two ongoing projects in Northern Italy, pp. 221-226. Proceedings of Photogrammetrie und Forst Tagungsband, Freiburg (Germany), 1994.

Marchetti, M., Bottai, L., Chirici, G., Dissegna, M., Castagnoli, A., Oradini, A. 1997. Misure iperspettrali per la determinazione del livello di deperimento dei boschi del Consiglio, pp. 142-147. Proceedings of Conferenza Nazionale delle Associazioni Scientifiche per le Informazioni Territoriali ed Ambientali. Parma, ottobre 1997. Ed. Publitecnica spa: Roma.

Marchetti, M. and Gomarasca, M. 1998. Rilevamento dello stato della copertura vegetale tramite telerilevamento, con M.Gomarasca. *In* Monitoraggio delle foreste sotto stress ambientale, pp. 62-71. Edited by A.B.Denti, S.M.Cocucci, F.Sartori. Collana Ricerche & Risultati - Fondazione Lombardia per l'Ambiente: Milano.

Marchetti, M., Oradini, A., Mariotti, B., Cumer, A. 1998. Progetto TRANSITALIA: telerilevamento dei danni sulle foreste di aree appenniniche ed insulari. Documenti del territorio, 39: 20-40.

McKay, H.M. 1988. Non-pollutant abiotic factors affecting needle loss. *In* Scientific Basis of Forest Decline Symptomalogy, pp. 31-38. Edited by Cape, J.N., Mathy, P. Proceedings of a workshop jointly organised by the Commission of the European Communities and the Institute of Terrestial Ecology, Bush State Research Station: Edinburgh, Scotland, 21-24 March, 1988.

Nemani, R., Running, S.W. 1996. Implementation of a hierarchical global vegetation classification in ecosystem function models. Journal of Vegetation Science, 7: 337-346.

Nevalainen, S. and Yli-Kojola, H. 2000. Extent of abiotic damage and its relation to defoliation of conifers in Finland. Forest Ecology and Management, 135: 229-235.

Solantie, R. 1994. Effect of weather and climatological back-ground on snow damage of forests in southern Finland in November 1991. Silva Fenn. 28: 203-211.

Srinivasan, A. and Richards, J.A. 1990. Knowledge-based techniques for multi-source classification. International Journal of Remote Sensing, 11: 505-525.

Thomsen, M.G. and Nellemann, C. 1994. Isolation of natural factors affecting crown density and crown colour in coniferous forest: implications for monitoring of forest decline. Ambio 23(4-5): 251-254.

Webster, R., Rigling, A., Walthert, L. 1996. An analysis of crown condition of Picea, Fagus and Abies in relation to environment in Switzerland. Forestry 69(4): 347-355.

CONCEPTUAL ISSUES OF CLOSE-TO-NATURE SILVICULTURE AND BIODIVERSITY CONSERVATION AND RELATED MONITORING REQUIREMENTS

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Abstract
A review of the evolution of forestry thought and scientific and technical advances shows that the basic trends in silviculture can be traced to four different concepts: financial silviculture, ecologically based silviculture, nature oriented or close-to-nature silviculture, and systemic silviculture.
Financial silviculture, ecological and close-to-nature silviculture all refer to linear and intensive classic silviculture that is based on the principle of controlling natural processes through cultivation techniques. Close to nature silviculture tends towards uneven aged, selection forests. The current application of the selection system is based on a series of parameters that form an organized whole coherent with the aim of obtaining maximum wood production with minimum expenditure of energy, capital and labour. The aim is to guarantee the continuity of production. In fact, the productivity, yield and value of the forest are considered independent of the ecosystem.
Systemic, non-linear, extensive silviculture based on the principle of autopoiesis goes well beyond the concept of close-to-nature silviculture. The aim is to promote the system's biological complexity and hence productivity, yield and economic value of the forest are dependent upon the ecosystem. Furthermore, systemic silviculture implies local control.
Mediterranean forests, the fruit of man's long interaction with the environment, are rich in a diversity which today has a value that goes beyond the aesthetic: it is cultural and anthropological. Systemic silviculture gives man, in his cultural dimension, the role of an aware member of the biological community. Only management based on continuous monitoring and systemic silviculture can give a coherent response to the need for protecting biological diversity that includes, as an expression of culture, also the diversity produced by human activities.

Keywords: sustainable management, systemic silviculture, complexity, cultural environment

1. INTRODUCTION

Sustainable development is based on the harmony of growth processes among interacting systems. A review of the many definitions in the literature reveals the lack of a formal definition of sustainability. The environmental and ecological issues are complex and controversial.
It is universally recognized that the forest plays an important role in making the present liveable and the future possible. Notwithstanding the progress in the field of ecology and the evolution of forestry thought, silviculture, forest management and economics are still moving ahead according to the canons of linear processes and the mechanistic, reductionist paradigm.
Sustainable forest management must answer society's needs by first pursuing the goal of the efficiency of the forest biological system and secondly intra- and intergenerational equity. Therefore, a change is needed on several fronts: cultural and ethical, scientific and technological, political and regulatory as well as economic and social.
Today, the concept of sustainable management is associated with biodiversity. Sustainability and diversity are ecologically interrelated. Management of a renewable resource, such as the forest, is defined as sustainable when it is exploited within certain limits. Traditional forest management, based on the theory of the normal forest and on Rupf's (1960) wake effect, *Kielwassertheorie,* derived from Dietrich's (1941) "theory of functions" does not meet the criteria of conservation or recovery of biological diversity.
Many of the problems of the obvious unsustainability of traditional forest management come from the idea that wood is the main, if not sole, useful product of the forest. Sustaining wood production does not always mean sustaining the forest system.
For a long time the forest was considered a wood-producing machine, an out-door workshop. Even worse, in some cases it was exploited – and often still is – not as a renewable resource, but as mine from which to extract as much as possible in the shortest possible time.
In nineteenth century Europe, industrial expansion demanded intensive utilization of the forest. Forestry sciences had defined and codified rules for cultivation, planning and rational management that would promote economic and social development as well as the conservation and protection of the forest. The main purpose of silviculture, forest management and economics was – and for many foresters still is – to obtain the maximum monetary benefit and the maximum of goods and services for an unlimited time with the lowest outlay of energy, labour and capital.

New knowledge in the fields of biology, ecology and economics have allowed for a better understanding of the processes and interactions between the forest and the environment leading, albeit slowly, as appropriate to forestry issues, to substantial changes on both the theoretical and practical levels.
A review of the evolution of forestry thought and scientific and technical advances shows that the basic trends in silviculture can be traced to four different concepts: *financial silviculture, ecologically based silviculture, nature oriented* or *close-to-nature silviculture* (in this paper *nature oriented silviculture* and *close-to-nature silviculture* have the same meaning: hereinafter we shall use the term *close-to-nature silviculture),* and *systemic silviculture.*
Financial silviculture, ecological and close-to-nature silviculture all refer to linear and intensive *classic silviculture* that is based on the principle of controlling natural processes through cultivation techniques. Forest cultivation and management focus on the volume/regeneration relationship considered as a source of income and basis for the continuity of production, respectively. The aim is to guarantee the continuity of production. In fact, the productivity, yield and value of the forest are considered *independent* of the ecosystem.
The forest cannot be cultivated without keeping in mind the efficiency and functionality of the ecosystem. It would be neither scientifically valid nor technically acceptable. The forest is a complex biological system. This is the key, it is a system. And if it is true that the system concept is relatively new in forestry, it is just as true that the growing awareness of the importance of this concept has led to significant changes in the *definitions, goals* and *limits* of silviculture (Ciancio 1998).
In this paper we shall show that *systemic,* non-linear, extensive silviculture based on the principle of autopoiesis goes well beyond the concept of close-to-nature silviculture. Its aim is to promote the system's biological complexity and hence it acknowledges that the productivity, yield and economic value of the forest are *dependent* upon the ecosystem (Ciancio and Nocentini 1996).
Perhaps, a quick historical *excursus* could help understand how, over the years, silviculture has always moved up its boundaries, first arriving at close-to-nature silviculture and then at systemic silviculture.

2. FINANCIAL SILVICULTURE

Financial silviculture was born in Germany, when extensive clear cutting was carried out to meet industrial needs. "During the second half of the last century in slightly more than 40 years the ratio of broad-leaved and conifer forests was inverted from 2:1 to 1:2. In place of the ancient beech and oak forests there arose the monotonous and even extensions of pine and fir forests groves that were mostly comprised of single species" (Pavari 1959a).
Financial silviculture is based on a simplified management-cultivation system. It calls for the creation of even-aged, monospecific stands arranged in chronological classes. Treatment includes the indispensable procedures. Thinning is only done when it is financially advantageous. Rotations are correlated with purely financial criteria. Utilization is by clear-cutting and regeneration is artificial.

3. SILVICULTURE ON AN ECOLOGICAL BASIS

At the beginning of the XX century, studies on forest phytogeography, ecology and genetics became the basis for silviculture. The innovation consisted of considering silviculture both an art and a science.
With Dengler (1930) as Patrone (1979) affirms, "The propaedeutics to silviculture is now *forest ecology:* the climate, the soil, and so forth. Thus we want to *evaluate* the most advantageous species on the basis of an analysis of the station's main factors; this is the forest of *rationalism* which extends from financial-mathematical calculations to biology."
Silviculture on an ecological basis is a much more complex management system than financial silviculture. Basically, it can be defined as comparative silviculture. If we know the environment's macroscopic factors, specifically the climate and soil, and the requirements of the species, the silvicultural systems and methods that are applicable to a given forest can be replicated, *ceteris paribus,* in another forest with the same physiognomy if not the same composition. We use the species in the "right place." We perform cultivation and regeneration cuts in relation to the needs of the species. If regeneration does not occur, we proceed with artificial regeneration.
In brief, silviculture on an ecological basis calls for the formation of even-aged, monospecific stands with one, or at most two, secondary species arranged in chronological classes; one or more thinnings; and three main forms of treatment: *clear cutting (including strip clear cutting and patch clear cutting); seed tree method; and shelterwood method.*

4. NATURE ORIENTED AND CLOSE-TO-NATURE SILVICULTURE

A new way of conceiving and viewing the forest developed after the resounding failures due to the application of *financial silviculture* as theorized by the German school between the end of the XIX and the beginning of the XX centuries. And with this came a new method of cultivating and managing the forest. Silviculture and management focused on the application of methods with low environmental impact. The study of natural phenomena became crucial for identifying cultivation guidelines.

Parade (1883), with his aphorism *"imitez la nature, hâtez son oeuvre,"* [imitate nature, hasten its works] and Gayer (1901), with the equally famous maxim *"Zurück der Natur"* – back to nature – which, was an invitation on the one hand not to cultivate pure, even-aged forests and on the other, to work to achieve natural regeneration, were the precursors of *nature oriented silviculture.* Gayer (1901) corroborated the concept of the return to nature by stating that *"In der Harmonie aller im Walde wirkenden Kraefte, liegt das Raetsel der Produktion,"* – silviculture in harmony with nature is conceived in the spirit of a the "quest for a harmonization of natural forces of production."

Nature oriented silviculture is a management system that has its roots in tradition and local culture. It was codified into a system at the end of the XIX century as a reaction to the excessive artificiality of the financial silviculture that was typical in Central Europe. For a long time it was contested by both foresters and administrators because it was erroneously likened to a form of silviculture based on a commercial type harvesting method. Over the years it became established as a management system that is indeed respectful of the continuity of production.

In the XIX century, selection or thinning felling, closely tied to the mixed and uneven-aged forest, that is the basic treatment of close-to-nature silviculture, was not considered a true management system. More often it was deemed a commercial cut that had nothing to do with the specific cultivation goals (Ciancio and Nocentini 1997a).

It is sufficient to remember that in 1883 a law was passed in Baden-Wuerttemberg prohibiting group shelterwood and group selection felling (*Femel* and *Plenter*). This law, according to Wolf von Honkenjos (1993; 1995) was considered progressive and liberal and remained in force for 143 years, that is until 1976. But only in 1992 – after 159 years – did the Ministry for Agriculture and Forestry of Baden-Wuerttemberg, issue a decree urging the foresters to apply *Femel* and *Plenter* in forest regulation plans.

Close-to-nature silviculture aims at the *paranatural forest.* It calls for different treatments that are suited to the different situations and that can be traced to three basic methods. The first comprises *group shelterwood cutting*; the second is characterized by *combined cutting:* selection and group shelterwood; the third calls for *classic single tree selection cutting.* Regeneration is natural.

In Germany especially, *close-to-nature silviculture* has been the subject of heated debates. The clashes filled pages and pages of forestry journals. The issue on which the discussion degenerated into arguments that often exceeded the boundaries of normal scientific debate, was *nature-like silviculture* that gave rise to Moller's *Dauerwald* or "permanent forest" and *close-to-nature silviculture.* There was no discussion, they railed and shouted; they showed no respect for the others' ideas. Scientific and cultural prejudice became ideology. A superficial review would make it seem that the differences are slight, actually there is a totally different way of interpreting silviculture.

According to Leibundgut, 1987 (in Schütz 1990) and many Central European foresters, *nature-like silviculture* is "a silviculture that is totally and blindly subject to the strictly natural character of the stand." And it represents "a more narrow, almost dogmatic track than nature oriented silviculture." On the other hand, *close-to-nature silviculture* is based on the spirit of finding harmony among the forces of production and it uses nature's potential, for example, working with a broad range of species, including the hosts.

Currently, close-to-nature silviculture is defined as the emulation of the development cycles of natural forests. Central and Northern European foresters distinguish two forms of close-to-nature silviculture in relation to the manner in which the natural forests develop in the various areas:

- for the natural boreal forests they identify a natural model distinguished by catastrophic disturbances that cause the destruction of forest cover over vast areas and subsequent regeneration. Among these the main factor is fire that occurs at 30-120 year intervals in the northern forests (Esseen at al. 1997). In these areas close-to-nature silviculture focuses on maintaining the mosaic of structures at the regional level;
- in Central Europe the basic principles of close-to-nature silviculture are identified in the small scale or *gap disturbances* and aim at the formation of mixed, prevalently broad-leaved forests.

Res sic stantibus, a pause for reflection is needed. Often foresters – knowingly or unknowingly, it really does not matter – ignore the obvious: nature acts through random events. Not taking this into account is a serious error. It is obvious that random events cannot be predicted either as to recurrence or intensity. And the feedback mechanisms of the forest system following these events are equally unpredictable.

Silviculture, on the other hand, proceeds according to defined and organized methods, i.e. according to scientifically codified procedures. That is why no one form of silviculture can be nature-like, if anything – with emphasis on if anything – it can be close-to-nature.

In fact, classic silviculture has always applied a single-cause single-effect approach. For example, a species that is shade intolerant is clear-cut without considering, as Behan (1997) has pointed out, that this simplistic practice causes a complicated set of consequences we are only beginning to comprehend, and not only in the forest itself, but in society at large. Furthermore, it is also well known that shade intolerant species regenerate naturally in stands with a composite structure. Classic examples are Huffel's futaie claire system for oak in France (Huffel 1926; Ciancio et al. 1995) and the stone pine forests in Spain, Turkey and Italy (Pavari 1954; Ciancio et al. 1986; Montero and Cañellas 2000). Accurate investigations have shown that many natural forests both in Northern Europe and in North America, commonly believed to be even aged, are instead uneven aged (Lahde et al. 1991; Buongiorno 1996).

5. THE UNEVEN-AGED FOREST

In its most precise meaning, close-to-nature silviculture refers to the uneven-aged forest. The question that arises spontaneously is, what exactly do we mean by uneven-aged forest.

Science has defined the features of the uneven-aged forest. It is a forest distinguished by a permanent cover and almost continuous regeneration. It is a forest comprising an aggregate of differently aged trees of various sizes (diameter and height) individually and intimately mixed.

In the virgin forests that are composed mostly of shade-tolerant species, i.e. mixed and stratified, the natural sequence that makes it possible to achieve and maintain a condition of dynamic equilibrium over time, requires abundant regeneration in the gaps created by the death and fall of big, old trees. Then natural selection makes sure that only one of the young plants will occupy the space left by the dead trees, thus recreating the preexisting situation.

The existing, cultivated uneven-aged forest is stratified and depends on selection cutting. This treatment calls for frequent interventions repeated every *n* years (cutting cycle) that remove mature trees (usually those that have attained the maximum diameter *Dr*) and thin the smaller trees (both older, dominated, trees and younger ones that are in excess number compared to the balanced structure).

The uneven-aged forest we described above is quite rare. Where it does exist it is the utmost of forest cultivation. Patrone (1975; 1979) defines it as *punctiform* or single tree selection forest. It is characterized by:

a) almost continuous regeneration;
b) lack of a defined rotation, replaced by maximum diameter and by contemporaneous regeneration felling and thinning;
c) complete cover and stratified structure;
d) considerable photosynthetic activity, since all the strata are photosynthesizing and the activity involves all the vertical space;
e) generally mixed composition;
f) lower absolute growing stock with respect to even-aged forests, but uniformly distributed over the entire area with little variations over time;
g) absence of correlation between diameter and age of trees (or if there is a correlation it is *sensu latu* since the diameter is strongly influenced by the social position of the trees);
h) absence of felling margins.

These points, that are equally typical and important, give a picture of the marked complexity of the uneven-aged forest which, when there are no major disturbances, corresponds to equally marked stability and hence, one of the highest levels of biological efficiency among the various forest formations.

Since in a compartment, theoretically, there are all the diameter classes, from the smallest to the biggest, a balanced uneven-aged stand can be considered a true sustained yield unit, giving an annual product. Each compartment is thus a unit comprising many parts (single trees or small groups) which succeed each other in the area in a more or less disorderly manner. Actually, the disorder is more apparent than real because the organization of the parts (trees or small groups) follows specific laws – uniformities – that are very complex, and for this reason, still little known.

In practice, selection cutting occurs in the same section every *n years* where *n* is equal to the length of the cutting cycle. This means that the normal uneven-aged forest consists of *n* plots each of which enters the cutting cycle every *n* years and yields a product equal to *n* increments.

Defining the normal state of an uneven aged forest means defining the composition, structure and growing stock of a stand that gives a maximum and more or less constant product every *n* years.

Another way of defining the uneven-aged forest, is as an aggregate of even-aged microstands each of which extends over less than 1000 m^2. This is the *futaie jardinée par bouquets,* as the French call it. Patrone (1975) defines it as the atomistic forest to distinguish it from the molecular forest formed by even-aged stands on areas 1000 – 5000 m^2 that the French call *futaie par parquets.*

The parameters that characterise the balanced uneven-aged forest are:

1) normal diameter distribution;
2) diameter increment and passage time;
3) growing stock;
4) maximum diameter;
5) cutting cycle;
6) volume growth rate;
7) computation of growing stock in size classes;
8) ingrowth or recruitment.

These parameters are examined in the Appendix.

6. SYSTEMIC SILVICULTURE

The forest is not merely a group of trees with economic value. It is an *adaptive system* that learns and evolves. It comprises single *adaptive agents* that function as complex systems with each adjusting itself to the others' behaviour.

Silviculture is the study, cultivation and use of the forest, an extremely complex, autopoietic system that is capable of autonomous self-perpetuation and of accomplishing multiple functions (Ciancio 1998).
If this is the definition of silviculture, then the *aims* are:

a) maintaining the forest system in balance with the environment;
b) conserving and augmenting biodiversity, and in more general terms, the system's complexity;
c) achieving congruency of the management activities with the other systems with which the forest interacts.

The *limits* are defined by the criteria applicable to the use of renewable resources. According to these criteria, the utilization and harvesting of products:

1) should not exceed the rate at which the forest resource regenerates;
2) should not affect the system's evolutionary potential;
3) should not reduce biodiversity.

Systemic silviculture permits the sustainable management of the forest. It can be configured with man's activities as an essential component of the forest system. *Systemic, extensive, non-linear silviculture* is based on the principle of autopoesis. It works on behalf of the forest, that is to say, according to a cultivation algorithm with the aim of preserving, conserving, enhancing and favouring the system's biological complexity in a co-evolutionary *continuum* which, *de facto,* excludes the *finalism* typical of linear processes that lead to the *normalization* of the forest (Ciancio et al. 1994a; 1994b).
In order to avoid problems that are always possible, it is necessary to make flexible choices so as to discover errors and correct them promptly at the lowest possible cost. In brief, in silviculture we must abandon the positivist approach that is still dominant in some academic and research fields and adopt the approach based on the scientific attitude of "trial and error" (Ciancio and Nocentini 1997b).
In addition to conferring efficiency on the forest ecosystem, the algorithmic concept of interventions maintains biodiversity and creates a new and different relationship between man and the forest. It is a relationship in which man is the forest's referent and not the one who bends the system to his needs. In other words, the forester "reads" the forest and works accordingly, replacing the culture of dominating and controlling nature with the culture of respecting nature.
Systemic silviculture calls for natural regeneration and low environmental impact actions, that aim at conserving and incrementing the system's biological diversity. It supports dishomogeneity and structural and compositive diversifications in order to enhance the capacity for self-organization and integration of all the biotic and abiotic components of the forest. This, above all, helps to overcome the conflict between two extreme views: on the one side those who consider the forest as a non-disposable asset, and on the other, those who consider the forest as totally disposable to be exploited according to market laws.
At the management level, the application of systemic silviculture requires a change in approach with respect to classic silviculture (Table 1). Classic silviculture tends towards a predefined structure: management is based on centralized control and cultivation uniformity.
The cultivation unit is the stand. Silvicultural and utilization interventions are *cautious, continuous and capillary* - the "three C's of silviculture" - in relation to the needs of the various stands. The aim is to act effectively on the ecosystem's evolutionary processes without excessively disrupting or upsetting its organization. Cultivation interventions take into account all the organisms that interact within the forest and not just the trees. The forest is dishomogeneous and unstructured. Its composition is mixed. The cycle is indefinite. Regeneration is natural and continuous. Monitoring, controlling and verifying the evolutionary processes are the essential elements for remedying errors. The allowable cut is silvicultural and periodic. Management aims towards conserving and increasing complexity and creating autopoietic forest-systems in balance with the environment. Finally, systemic management implies decentralized control and cultivation diversification.

TABLE 1: Sustainable forest management: classic vs. systemic silviculture and management

Classic silviculture and management	Systemic silviculture and management
Predetermined forest structure	Unstructured forest: forest structure undefined in time and space
Selection of species	Spontaneous mix
Management unit: - even-aged forest → felling series - uneven-aged forest→ compartment	Cultivation unit: the stand
Predefined silvicultural treatment	Cautious, continuous, capillary interventions with the aim of following the ecosystem's evolutionary processes
Cultivation cycle: -even-aged forest → rotation -uneven-aged forest → cutting diameter	CULTIVATION CYCLE: Undefined
NORMAL STRUCTURE: -even-aged forest→ balanced age classes	SELF-ORGANISATION OF THE FOREST: verification of the evolutionary processes

-uneven-aged forest→ balanced diameter classes	
Predetermined allowable cut	Allowable cut depending on silvicultural criteria
Constant and maximum annual product Simplified forest	Periodic product Conserved and increased complexity
Cultivation uniformity requires centralized control in relation to profit and market	Cultivation diversity requires decentralized control and enhances "local knowledge"

7. CONCLUSIONS

Sustainable management and biodiversity conservation have become the focal points of forestry. Classic silviculture has tried to respond with small technical measures that have not always enjoyed adequate scientific support. The gap that has opened between the old – close-to-nature silviculture – and the new – systemic silviculture – is incommensurately wide.

In order to answer coherently to the need of conserving biodiversity in forest systems, we propose a new "open project" fostering the transition from the technocratic and productivistic approach to the systemic one. Only by respecting the forest's self-organization and not predetermining its structure will it be possible to conserve or increase biodiversity. This means moving from classic, linear silviculture, that includes close-to-nature silviculture, to systemic silviculture which, by adopting an eco-centric standpoint makes it possible to expand the spectrum of values at stake and base conservation on the intrinsic value of nature in general and of the ecosystems in particular (Nocentini 2001, in press).

The concept of biodiversity does not merely encompass the issue of protecting rare or endangered plant and animal species, and the habitat in which they live, or the number and diffusion of the species. The concept of biodiversity projects the problem far beyond the protection of individual species or biotopes. It involves the ecosystems and their functioning and includes the co-evolutionary processes among their respective components. Diverse ecosystems give rise to different life forms, habitats and cultures whose co-evolution leads to the conservation of biodiversity.

Mediterranean forests, the fruit of man's long interaction with the environment, are rich in a diversity which today has a value that goes beyond the esthetic: it is cultural and anthropological. Systemic silviculture gives man, in his cultural dimension, the role of an aware member of the biological community. Only management based on continuous monitoring and systemic silviculture can give a coherent response to the need for protecting biological diversity that includes, as an expression of culture, also the diversity produced by human activities.

"Times are changing". There is the need for an exercise of *logical hygiene*. The development that has taken place in recent years and the knowledge acquired in forestry sciences have led to a change in the conceptual approaches to the forest. The change invests a range of issues which, until a few decades ago, could not be taken into account because the needs of the moment led to considering soil conservation and wood production as the main goals to be pursued with all available means.

Perhaps the profound changes that have come with economic development have not been properly assessed. Many believed – and some still agree – that development should not be limited. They did not realize that *unlimited development is impossible in a finite environment*. This conceptual error has had a strong impact on forest management: the forest has always been considered and managed as connected only to the market and, therefore, isolated from other systems. But forest management cannot be based only on the principles of market economy (Ciancio and Nocentini 1995; 1997a). As Georgescu-Roegen (1976) has stated, the market alone leads to a greater resource consumption by the first generations, that is faster than it should. The market is incapable of preventing resource degradation and then exhaustion by the first generations. This is clearly demonstrated by the fact that many mountain areas in the Mediterranean region have been deforested precisely because the price of wood was "right". Only with severe restrictions to cutting this has been partly remedied. This proves that where there are negative externalities or external diseconomies, there is also market failure and the regulating intervention of public authority is necessary.

In recent years the growing awareness that the forest is a complex biological system has raised ethical problems that are difficult to resolve. Perhaps it would be wise to focus on one idea. The *overall intellectual landscape* has changed and the outcome of this change is a different, vaster and more complete view of the forest.

The forest is the issue of interactions between organisms and the environment. According to the theory of the autopoesis, living systems maintain their specific identities in spite of continuous changes in their components (Maturana and Varela 1992).

On the scientific level, research has tried to demonstrate that complex biological systems can be understood only with a reductionist approach. This view is strongly supported by advocates of "esthetics" in science. They would like a rigorous, precise and elegant science, like Newton's mathematics.

Since the time of Plato "esthetics" has inspired a concept of science in which everything is beautiful, symmetrical and can be deduced from a few basic principles. Our concept, however, agrees with those – and there are many – who believe that "esthetics" in nature becomes science because it derives from formidable complexities that can also be found at the most elementary levels.

Understanding the forest as a whole guides the understanding of its parts and in turn knowledge of the role of the single parts helps in understanding the forest. Holism and reductionism are two sides of the same coin. One is opposite to and complements the other. The scientific paradigm is radically different, but the objective is the same: to pursue the highest level of knowledge of nature.

In this context man has both the right and the duty to work within the limits of the forest system's functionality, that is without reducing its complexity and diversity since he is part of the system with which he interacts.

"Each action is knowledge, and all knowledge is action," according to Maturana and Varela (1992). In silviculture this translates into acting "with wisdom" in the sense of a unity between science and ethics (Ciancio and Nocentini 1997c). Perhaps only in this way can we implement true close-to-nature silviculture.

REFERENCES

Behan, R. W. 1997. Scarcity, simplicity, separatism, science – and systems. *In* Creating a Forestry for the 21st century. The Science of Ecosystem management, pp: 441-417. Edited by Kohm K. A., Franklin J. F. Island Press: Washington, D.C.

Biolley, H. 1916. - L'anomalie du "materiel normal". Journal Forestier Suisse.

Biolley, H. 1920. L'aménagement des forêts par la méthode experimentale et spécialement la méthode du contrôle. Attinger Frères: Neuchatel.

Buongiorno, J. 1996. Uneven-aged management in Europe and North America : new methods for old concepts. The S.J. Hall Lectureship in Industrial Forestry, April 12. University of California, Berkeley. Department of Forestry and Resource Management. College of Natural Resources. 29 p.

Burel, A. 1888. Étude sur la constitution normale des forêts jardinées. Paris.

Cantiani, M. 1986. La determinazione dello stato normale. *In* Nuove metodologie nella elaborazione dei piani di assestamento dei boschi. ISEA: Bologna.

Ciancio, O. 1998. Gestione forestale e sviluppo sostenibile. Atti del Secondo Congresso Nazionale di Selvicoltura: Venezia, giugno 1998.

Ciancio, O., Iovino, F., Nocentini, S. 1994a. The theory of the normal forest. L'Italia Forestale e Montana, 49 (5): 446-462.

Ciancio, O., Iovino, F., Nocentini, S. 1994b. Still more on the theory of the normal forest: why we insist on saying no to it. L'Italia Forestale e Montana, 50 (2): 118-134.

Ciancio, O., Iovino, O., Menguzzato, G., Nocentini, S. 1995. Huffel's "fûtaie claire": a little known silvicultural and management system. La fustaia chiara: un sistema di trattamento e di gestione poco noto. L'Italia forestale e montana 50 (3): 262- 273.

Ciancio, O., Nocentini, S. 1995. Nuovi orientamenti in selvicoltura. *In* Giornate di studio sul "Global change", il verde per la difesa ed il ripristino ambientale. 6ª giornata: il ruolo della selvicoltura per la difesa e il ripristino dell'ambiente. I Georgofili. Atti dell'Accademia dei Georgofili. 7. ser., vol.XLII: 11-153.

Ciancio, O., Nocentini, S. 1996. Systemic silviculture: scientific and technical consequences. L'Italia Forestale e Montana, 51 (2): 112-130.

Ciancio, O., Nocentini, S. 1997a. The forest and man: the evolution of forestry thought from modern humanism to the culture of complexity. Systemic silviculture and management on natural bases, pp. 21-114. *In* "The forest and man". Edited by O. Ciancio. Accademia Italiana di Scienze Forestali: Firenze.

Ciancio, O., Nocentini, S. 1997b. The scientific paradigm, "good silviculture" and the wisdom of the forester, pp. 257-268. *In* "The forest and man". Edited by O. Ciancio. Accademia Italiana di Scienze Forestali: Firenze.

Ciancio, O., Nocentini, S., 1997c. Forest management between ecology, economics and ethics, pp. 223-236. *In* "The forest and man". Edited by O. Ciancio. Accademia Italiana di Scienze Forestali: Firenze.

Ciancio, O., Cutini, A., Mercurio, R., Veracini, A. 1986. Sulla struttura della pineta di pino domestico di Alberese. Annali Istituto Sperimentale per la Selvicoltura Vol. XVII: 171-236.

D'Alverny, A. 1927. Contre la note du 1883, pp. 515-516. Revue des Eaux et Forêts.

D'Alverny, A. 1935. Notes sur la densité des peuplements jardinés, pp. 515-516. Revue des Eaux et Forêts.

De Liocourt, F. 1898. De l'Aménagements des Sapinières. Bulletin Société Franche Comté et Belfort.

Dengler, A. 1930. Waldbauauf ökologischer Grundlage. Berlin.

Dietrich, V. 1941. Forstliche Betriebswirtschaftslehre. Bd. III, Erfolgsrechnung, Zielsetzung. Parey: Berlin et Hamburg.

Esseen, P.A., Ehnström, B., Ericson, L., Sjöberg, K. 1997. Boreal forests. Ecological Bulletins 46: 16-47. Copenhagen.

Favre, E. 1943. Cinquante années d'application de la Méthode du contrôle à la forêt de Couvet. Journal forestier Suisse : 121-123.

Flury Ph. 1914. Grösse und Aufbau des Normalvorrates im Hochwalde. Mitteilungen der Schweizerischen Centralanstalt für forstliche Versuchswesen. Zurich.

François, T. 1938. La composition théorique normale des futaies jardinées de Savoie. Reveau des eaux et Forêts, 1: 1-18.

Gayer, K. 1901. Traité de sylviculture. Traduzione da "Waldbau", Berlino, 1889 (seconda edizione): Bruges.

Georgescu-Roegen, N. 1976. Energy and Economic Myths. Pergamon Press: New York e Oxford.

Gurnaud, A. 1890.. La méthode du controle et la tradition forestière. Revue des eaux et forets: 209. 218.

Honckenjos von, W. 1993. Die Wiederentdeckung des Femelwaldes. Auf forstgeschichtlicher Spurensuche im Bücherschrank eines badischen Forstamtes. Allgemeine Forst und Jagdzeitung, 164 (12): 213-218.

Honckenjos von, W. 1995. Forstideologisches aus Baden. Allgemeine Forst und Jagdzeitung, 166 (2/3): 34-38.
Huffel, G. 1926. Economie forestière. Librairie Agricole de la Maison Rustique: Paris. Troisième édition.
Knuchel. H. 1953. Planning and control in the managed forest. (Translation by M. L. Anderson). Oliver and Boyd: Edimburgh. 360 p.
Lahde, E., Laiho, O., Norokorpi, Y., Saksa, T. 1991. The structure of advanced virgin forests in Finland. Scandinavian Journal of Forest resources 6: 527 – 537.
Leibundgut, H. 1987. Von Holzackerbau zum naturnahen Waldbau. Oesterr. Forstztg., 1(4): 10-11.
Maturana, H.R., Varela, F.J. 1992. L'albero della conoscenza. Garzanti Editore: Milano.
Meyer, H. A. 1933. Eine mathematisch-statistiche Untersuchung über den Aufbau des Plenterwaldes. Schweizerisch Zeitschrift für Forstwesen, pp. 33-46, 88-103, 124-131.
Möller, A. 1922. Der Dauerldgedanke. Sein Sinn und seine Bedeutung. Berlin.
Montero, G.; Cañellas, I. 2000. Selvicoltura de Pinus pinea L. Estado actual de los conocimientos en españa. Premier Simposio del Pino Piñonero (Pinus pinea L.). 22, 23 y 24 de febrero 2000. Valladolid. Tomo I, 21-38.
Parade, A. 1883. Cours élementaire de culture des bois. Sixième édition publiée par A. Lorentz et L. Tassy. Octave Doin, éditeur : Paris.
Patrone, G. 1944. Lezioni di assestamento forestale. Tip. Ricci: Firenze.
Patrone, G. 1975. Ricerche sulla fustaia disetanea del Cadore. Annali dell'Accademia Italiana di Scienze Forestali, Firenze, Vol. XXIV: 29-109.
Patrone, G. 1979. Stravaganza terza; la fustaia da dirado: realtà o fantasma? Annali Accademia Italiana di Scienze Forestali, Firenze, Vol. XXVIII: 267-306.
Pavari, A. 1954. Sul trattamento delle fustaie di pino domestico, pp. 69-97. *In* Atti del Congresso Nazionale di Selvicoltura per il miglioramento e la conservazione dei boschi italianai. Accademia Italiana di Scienze Forestali: Firenze.
Pavari, A. 1959. Basi ecologiche della selvicoltura europea. Scritti di ecologia, selvicoltura e botanica forestale. Accademia Italiana di Scienze Forestali: Firenze.
Perona, V. 1892. Selvicoltura generale. Milano.
Puton, A. 1890. Traité d'économie forestière (Aménagement). Paris.
Rupf, H. 1960. Wald und Mensch im Geschehen der Gegenwart. Jahresbericht des Deutschen Forstvereins.
Schaeffer, A., Gazin, A., D'Alverny, A. 1930. Sapinières. Paris.
Schütz, J.P. 1990. Sylviculture 1. Principes d'éducation des forêts. Lausanne, Presses Polytechn. et Univers. Romandes, 243 p.
Susmel, L. 1956. Leggi di variazione dei parametri della foresta disetanea normale. L'Italia forestale e montana 3.
Susmel, L. 1957. Caratteri ecologici vegetativi e strutturali dei boschi di Longarone. Annali dell'Accademia Italiana di Scienze Forestali, Firenze, Vol. VI: 21-129.
Susmel, L. 1980. Normalizzazione delle foreste alpine. Liviana: Padova.

APPENDIX - THE PARAMETERS OF THE UNEVEN-AGED FOREST

Close to nature silviculture, as explained above, tends towards uneven aged, selection forests. The current application of the selection system is based on the following parameters. These parameters form an organized whole that is coherent with the aim of obtaining maximum wood production with minimum expenditure of energy, capital and labour. This proves that close to nature silviculture is *independent* of the ecosystem.

The parameters of the balanced uneven aged selection forest are: 1) normal diameter distribution; 2) diameter increment and passage time; 3) growing stock; 4) maximum diameter; 5) cutting cycle; 6) volume growth rate; 7) computation of growing stock in large size classes; 8) ingrowth or recruitment.

The normal diameter distribution

The diameter distribution in a normal, balanced, uneven-aged forest is typical. With sufficient approximation and considering trees with dbh $\geq$ 17,5 cm, the normal diameter distribution follows an exponential curve.

If y is the number of trees in each diameter class ($\geq$ 17,5 cm) and k a constant typical of every forest, then:

$$y = k^{-x}$$

where: y = number of trees; k = constant that varies between 1.20 and 1.50 (more often 1.30-140) in relation to site quality; x = diameter class.

This is the empirical function that De Liocourt (1898) obtained by studying the diameter distributions in the Franche Comté silver fir forests. These fir forests had a growing stock per hectare of 318-412 m^2 and the maximum diameter was 80-90 cm.

According to De Liocourt's function, the number of trees in the various diameter classes decreases geometrically as the diameters increase:

$$y, yk, yk^2, yk^3, yk^4, yk^5, yk^6$$

where y is the number of trees in the highest dbh class (i.e. the number of trees with the maximum diameter), yk is number of trees in the next smallest diameter class, and so forth. The constant k is the ratio of the number of trees in successive diameter classes.

On the average the uneven-aged forest is characterized by 300-350 trees per hectare, a basal area of 30-35 m^2, to which 2-3 m^2 of trees with dbh $\leq$ 17,5 cm must be added, and a growing stock of 275-375 m^3.

Schaeffer, Gazin and D'Alverny (1930) have found that in uneven-aged silver fir stands the coefficient k falls between 1.30 and 1.55, going from the better sites to the worst.

The constancy of k (defined as mortality coefficient, or rather diminution coefficient) shows that the number of trees decreases at a constant rate as diameter increases. This means that mortality is constant as the trees pass from one diameter class to the next highest. But this law is only valid for average diameter distributions taken for large areas where there are different types of uneven-aged stands.

Meyer (1933), basing his work on the investigations of De Liocourt, expressed the diameter distribution of a balanced, uneven aged stand, by the following exponential equation:

$$y = ke^{-ax}$$

where : y = number of trees; x = dbh class; e = base of natural logarithms; a, k = constants for a characteristic diameter distribution.

In particular, a determines the rate by which the number of trees diminish in successive diameter classes, k indicates the relative density of the stand.

Other authors have considered the hypothesis that the trees in each diameter class occupy the same surface area (Burel 1888; Puton 1890; Perona 1892). If this hypothesis is true, then the number of trees per diameter class varies in a manner that is inversely proportional to the square of the diameter and hence according to a hyperbolic equation:

$$y = \frac{a}{x}$$

where: y = number of trees; a = constant; x = diameter class.

The constant a can be calculated from the following relationship:

$$a = \frac{xm}{xr - x20}$$

where: xm = mean stand dbh; xr = diameter class of the biggest trees (maximum diameter); $x20$ = 20 cm diameter class.

This type of equation would indicate that mortality decreases as diameter increases. However, according to Patrone (1975), this is not valid, for two main reasons. First: even if the correlation between diameter and age in the uneven-aged forest is not very strict, it is obvious that mortality increases as the diameter grows and not vice versa. Secondly: in the uneven-aged forests in general the trees in the smallest diameter classes grow beneath the canopies of the bigger trees and hence do not occupy a distinct area, while the trees in other diameter classes occupy an area that is directly proportional to their diameter. Therefore, the hypothesis of the equality of the surface area occupied by each diameter class is false. Furthermore, these considerations lead to the conclusion that, for the same growing stock and wood production, the uneven-aged forest requires a smaller surface area than the even-aged forest.

According to Patrone (1975) the diameter distribution can be expressed by a linear equation. This type of function would mean that mortality increases with the diameter. He concludes that, for maximum diameter (Dr) $\leq$ 65 cm, the linear law is the one that best expresses the phenomenon of selection.

On the basis of studies conducted at Longarone, S. Vito di Cadore and Comelico, Susmel (1956) constructed the normal diameter distribution starting from diameter class 35 cm where he had found that the number of trees (N) was always very close to 33. In practice the normal diameter distribution is obtained by multiplying 33 by k for diameter class 30, then this value again by k for diameter class 25, then again for the class 20 cm. The number of trees for the diameter classes above 35 cm are obtained by dividing 33 by k, and so on, up to the maximum diameter Dr.

According to Susmel, the coefficient k is related to the mean height of the 3-4 tallest trees in of the stand (*statura*, S) according to the following equation:

$$k = 4.5 : \sqrt[3]{S}$$

in the case of pure beech or mixed beech forests with 25% (number of trees) oak, silver fir and spruce;

$$k = 4.3 : \sqrt[3]{S}$$

in the case of pure silver fir or spruce forests; mixed forests with varying proportions of spruce and silver fir; mixed silver fir-spruce with not more than 25% beech; mixed silver fir-beech; mixed spruce-beech with subordinated larch and Scotch pine.

According to Patrone (1975) and Cantiani (1986) the constancy of k, for diameter classes greater than 20 cm, especially in the case of small samples, is a theoretical abstraction that is not empirically confirmed. In the case of small samples they maintain that k increases as the diameter increases.

Diameter increment and passage time

The diameter increment increases slowly as tree diameter increases. This means that in the uneven-aged forest diameter increment is proportional to the size of the trees. There are three main reasons for this:

1) the biggest trees are not usually the oldest, but rather the most vigorous due to natural and artificial selection;

2) cutting eliminates the strongest and fastest growing trees as diameter increases;
3) young trees generally grow more slowly because of the reduced growing space, while the trees in the bigger diameter classes maintain a relatively high growth rate over long periods.

Experience has shown that diameter increment varies from 2.5 to 3.5 mm for diameter class 20 and from 4 to 5 mm for diameter class 60 cm. But data also show that the thickness of the outermost rings on each tree in an selection forest is very variable: in the same diameter class there are trees in which the last ring is ½ mm wide and trees with a last ring of 4-5 mm. This is because a tree's diameter growth is an individual phenomenon: the rule according to which diameter increment increases with diameter is only valid for large averages. However, within the usual diameter range (20-60 cm), diameter increment is often considered constant.

Constant diameter increment means that the amount of time (τ or *passage time*, Knuchel, 1953) that, on the average, a tree in a diameter class takes to reach the next higher class, is constant and hence is equal to the number of rings contained in the last 2.5 cm of tree radius (for 5 cm diameter classes). But in reality, τ decreases slowly as the diameter increases.

Passage time is inversely proportional to diameter increment: i.e. it decreases slowly as diameter grows. For 5 cm diameter classes, diameter increment (Id) is equal to:

$$Id = \frac{2 \times 2{,}5}{\tau}$$

where: τ = number of growth rings in the outermost 2,5 cm radius, i.e. passage time.

Site quality has a considerable effect on τ. Given identical conditions, the more fertile the site, the shorter is τ. In general, τ varies from 8 to 25 years, and more frequently from 10 (better sites) to 15 (average sites) to 20 (low quality sites).

François (1938) in the French Alps, and Favre (1943) in Switzerland, have found that τ decreases as the diameter grows according to a curve that is steeper for the smaller diameter classes, and then tends to smooth out in the bigger classes. The period τ also varies with cultivation intensity: frequent cuts, that give light and space to the trees promote individual growth and tend to shorten τ.

Growing stock

The growing stock of the normal, balanced single tree selection forest, depends on composition, structure (diameter distribution), density and site quality.

As shown above, the normal diameter distribution is expressed by an exponential curve: $y = k^{-x}$; where k varies from 1.20 to 1.50 according to site quality and is constant for every forest.

Density of the balanced selection forest must be within a range that assure:

a) practically continuous natural regeneration;
b) the best living and growth conditions for the trees in the various diameter classes.

According to Patrone (1944) the maximum basal area compatible with regeneration is 37-38 m^2 per hectare. But this density of 37-38 m^2 ha^{-1} is only compatible with regeneration in very good sites. For forests with average fertility, the normal basal area does not exceed 30 m^2 ha^{-1}.

According to D'alverny (1935) in forests where the mean height of the trees that have attained maximum diameter (h) is equal to 30 m, the normal basal area oscillates around 31 m^2 ha^{-1}; in all other cases the normal basal area is obtained from the following equation:

$$G = 31\frac{\sqrt{h}}{\sqrt{30}} = \sim 5{,}7\sqrt{h}$$

These values refer to mixed spruce and silver fir forests or mixed forests where there is a prevalence of silver fir.

In practice, however, normal density is expressed by the growing stock. The question is to establish what is the optimum level of growing stock that at the same time guarantees natural regeneration and produces the maximum increment.

In general, and within certain limits, an increase in growing stock corresponds to a greater volume increment. On the other hand, given equal conditions, i.e. for the same k, τ and Dr, growth rate decreases as the growing stock increases. The question that has been hotly debated among foresters is then the following: is it appropriate to consider the growing stock that guarantees the maximum volume increment or the one that provides the higher growth rate?

The crux of the issue of the uneven-aged forest and its management has been in this question. Flury (1914) asked how high the growing stock must be while Biolley (1916) asked how low it should be. In fact, for a high growth rate the growing stock must be low, but still above the limit that provides an annual income. For a high volume increment the level of growing stock must be high, but not so high as to compromise regeneration.

The normal growing stock of the selection forest oscillates between these limits. Usually private owners manage the forest in order to obtain a high growth rate, that is low growing stock, while public agencies should regulate the forest so as to obtain a high volume increment, that is a high growing stock.

In practice, however, it is difficult to determine those limits. They can be determined by comparison because the normal growing stock (*Pn)* is also contingent upon maximum diameter (*Dr)*, site quality, diameter increment, the τ period, and rate of selection, k.

Normal growing stock varies from region to region. According to Patrone (1944) the growing stock that can give high economic yields is between 250 and 450 m^2 per hectare.
According to Schaeffer the normal growing stock (Pn) compatible with regeneration is equal to:

$$Pn = 10 \cdot S$$

where: S = mean height of the tallest trees.
According to D'Alverny (1935) the normal growing stock of the uneven-aged forests with a mean height of 30 m is equal to 320 sylve, from which:

$$Pn = 320\frac{\sqrt{h}}{\sqrt{30}} = \sim 58{,}4\sqrt{h}$$

where h is the height of the trees that have attained the maximum diameter.
According to Susmel (1956; 1980) the normal growing stock Pn in m^3 per hectare, the number of trees N, the basal area G in $m^2\ ha^{-1}$ and the maximum diameter $Dmax$ are all related to the mean height (S) of the 3-4 tallest trees per hectare. Assuming k to be constant, these parameters are linked to stature by the following relations:
a) beech forests or prevalently beech with oaks, silver fir and spruce less than 25% of number of trees:
$N = \sim 225$
$G = 0{,}65$ S (~ 2/3 di S)
$Pn = S^2/4$
$Dmax = 2.3$ S
b) pure silver fir or spruce forests or mixed silver fir-spruce or silver fir, spruce and with up to 25% beech, or mixed silver fir-beech, or spruce-beech with subordinated Scotch pine and larch:
$N = 330$
$Gn = 0.97$ S (~S)
$Pn = S^2/3$
$Dmax = 2.64\ S$
These relationships, experimentally obtained, can be useful as a general guideline in selection forest management.

Maximum diameter
The maximum diameter Dr increases with site quality and growing stock. The choice of the maximum diameter therefore is connected with the optimal growing stock and must be based on experimentally ascertained data. According to the Italian school, the maximum diameter was usually set around 40-45 cm (Patrone 1944; 1975). A felling diameter between 40 and 60 cm with growing stocks varying from 200 to 400 $m^2\ ha^{-1}$ seems to be the most appropriate because it allows for good wood production. Bigger diameters are usually not considered for biological reasons (the presence of overly big trees may hinder regeneration), for technical reasons (expensive and difficult felling) and for financial reasons (because the growth rate is usually satisfying within these limits).

The cutting cycle
The cutting cycle is the period of time between one cutting and the next. Theoretically, the normal balanced uneven-aged forest, even for single compartments, gives an annual yield consisting of the trees that have attained the maximum diameter and of all those trees of smaller diameter that are cut to maintain a balanced diameter distribution. But for practical reasons it is not possible to return every year on the same compartment: the costs would be too high and the income low. Hence the need for a certain number of years to elapse between one selection cut and the next so that not one but several increments can be collected and a certain number of trees can be harvested from the area. Each year the selection cut should be carried out on a surface area s such that:

$$s = \frac{S}{\lambda}$$

where: λ = number of years of the cutting cycle.
For silvicultural reasons a short cutting cycle, less than 10-12 years should be preferred so as to mould the stand with frequent, moderate cuts. This is because the positive effect of the selection cut ceases after 5-6 years in fertile sites and 10-12 years in low quality sites, and also because very heavy cuts could modify structure and growing stock.
Therefore the cutting cycle λ is roughly equal to half the period τ:

$$\lambda = \frac{1}{2}\tau$$

When the cutting cycle λ is equal to half the period τ it is recommended to cut between 16% and 20% of the growing stock; cutting 13-15% of the growing stock is feeble a low cut, while more than 25% is never strongly recommended.

Volume growth rate
Annual volume increment and growth rate (i.e. percentage volume increment) vary according to many factors: species, site quality, diameter increment, maximum diameter and stand density.
The annual volume increment of a tree increases with its diameter and hence, the volume growth rate decreases as the tree diameter increases. In fact, since the growth rate ipt is expressed by (Patrone 1944):

$$ipt = c \times \frac{dx}{x}$$

where: c = constant that is related to height increment and of to tree shape; dx = dbh increment; x = dbh
Thus, for a constant dx (diameter increment) as x (the diameter) increases the *ipt* (growth rate) decreases.
Considering a stand, the volume growth rate diminishes as the maximum diameter increases. In low quality sites, where τ is higher (i.e. diameter increment is smaller) volume growth rate is also lower.
According to Schaeffer *et al.* (1930) growth rate varies as follows:
3% (high quality sites) when τ = 11 years
2.5% (average sites) when τ = 13 years
2% (low quality sites) when τ = 16-17 years
Under average conditions the annual volume increment ranges from 4 to 12 m^3 per hectare.

Computation of growing stock in large size classes
The diameter distribution tends to give a mathematical form to the balanced state in the uneven-aged forest. But not everyone agrees with this. Actually, these attempts tend to schematize silviculture, to imprison it in formulas that do not always give reliable results.
In the uneven-aged forest the growing stock can be computed by very large size classes, i.e.:
W_1 = volume of large trees (55 cm and above)
W_2 = volume of medium size trees (from 35 to 50 cm)
W_3 = volume of small trees (from 20 to 30 cm)
According to Biolley (1920) the *étale* (equilibrium state) is reached when:

$$W_1:W_2:W_3 = 5:3:2$$

This distribution applies to good quality sites and for stands with very large maximum diameters (Flury 1914).
In the silver fir forests of the Vosges, Jura and French Alps, D'Alverny (1927) found a relationship between the growing stock of large trees (W_1) and medium size trees (W_2) approximately equal to:

$$W_1:W_2 = 3:5$$

with an inverse ratio compared to the one given by Biolley.
Mélard considers:
W_1 = volume of trees with dbh between 2/3 *xr* (maximum diameter) and *xr*
W_2 = volume of trees with dbh between 1/3 *xr* and 2/3 *xr*
W_3 = volume of trees with dbh smaller than 1/3 *xr*
and $W_1:W_2 = 5:3$
In practice Mélard's limits are less rigid than Biolley's but the ratio is the same.

Ingrowth or recruitment
During every period or cutting cycle a certain number of trees grows into the smallest inventoried dbh class, i.e. 17,5 cm. The number and the volume of these trees is the recruitment or ingrowth. This can be calculated with repeated inventories as follows:

$$N_{pf} = N_2 + N_u - N_1$$

$$V_{pf} = N_{pf} \cdot vu_{20}$$

where: N_{pf} = number of trees that during the period grow above 17,5 cm dbh; N_1 = number of trees in the first inventory; N_2 = number of trees in the second inventory; N_u = number of trees felled during the period; V_{pf} = volume of trees that during the period grow above 17,5 cm dbh; vu_{20} = volume (in *sylve*) of one tree in diameter class 20 cm.
In a balanced selection forest the number of trees that in a given period grow above 17,5 cm dbh should equal the number of trees that are cut in the same period. This is why ingrowth or recruitment is important for reaching and maintaining a balanced uneven aged structure.
According to Gurnaud (in Knuchel 1953) ingrowth less than 1,5 sylve per hectare is insufficient. The same limit is considered by Schaeffer *et al.* (1930) who identify three different situations in silver fir selection forests:

$V_{pf} > 2$ *sv* ha^{-1}: high ingrowth

1,5 *sv* $ha^{-1} < V_{pf} < 2$ *sv* ha^{-1}: satisfying ingrowth

$V_{pf} < 1,5$ *sv* ha^{-1}: unsatisfying ingrowth

Ingrowth depends on two different phenomena:
1) natural regeneration establishment and development rate;
2) growth rate of the young plants.

The first element depends from many different factors among which the main are seed abundance, soil and light conditions, presence of predators.

Growth of young plants depends above all on competition. If recruitment is insufficient all these elements must be accurately examined.

Digital analysis of multitemporal aerial images for forest and landscape change detection

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Abstract

The results of a research evaluating vegetation and landscape changes in an area of Valle Cannobina (north-east Piemonte, Italy) using GIS and aerial images are presented. GRASS GIS has been used to analyse different aerial photos taken in different years (1954, 1977, 1986, 1996). The images are very different: panchromatic, colour images and Infra-Red images in false colour; this situation is very usual in collecting real data and the integration of such a different material can be carried out only with efficient tools. GRASS GIS analysis modules permit the ortho-rectification of the aerial photos and their elaboration with supervised and unsupervised classification techniques to obtain vegetation coverage. As many other mountain Italian regions, the population in the study area is decreasing and this fact directly influences landscape and forest management criteria. Large pastures and agriculture areas are being covered by trees or bushes: this fact not only changes how the landscape is perceived by people but may also influence the elements cycles. Even if this is a well-known trend, it is very difficult to evaluate the extension and the evolution of these phenomena as requested by some specific studies on applied ecology and sustainable development. The present work has underlined the capability of GRASS in extracting all the available vegetation information from such a heterogeneous material. The modules of GRASS GIS allows the evaluation of landscape changes occurred in the area and many ecological information can be deduced from such maps. Considering that the presence of heterogeneous material is quite usual, this method to evaluate landscape changes seems to be powerful and useful in many different situations.

Keywords: GIS, multitemporal images, landscape change detection

1. Introduction

The abandon of traditional agricultural and forest activities has brought deep and sometimes irreversible changes in the mountain landscape not only in Italy but also in all the most developed European countries. A complex mosaic of ecosystems, which was the result of the application of diversified management methods, made once the landscape; nowadays the landscape is becoming more and more homogeneous.

As it has happened in many other mountain Italian regions, the population in Valle Cannobina, Piemonte, Italy, is decreasing and this fact directly influences landscape and forest management criteria. Trees or bushes are covering large pastures and agriculture areas: this fact not only changes how the landscape is perceived by people but may also influence the elements cycles. Even if the existence of the trend is well known, it is very difficult to evaluate the extension and the evolution of these phenomena as requested by specific studies on applied ecology and sustainable development (Ciolli and Zatelli, 1999). The phenomenon is already increasing since many years, but only recently some of the possible consequences on the mountain ecosystems and land sustainability have become clear. The old traditional mountain activities assured a certain level of land control and stability conservation against natural risks, they assured a high eco and bio diversity and guaranteed landscape peculiarities.

The purpose of the present research is to analyse different aerial photographs to investigate landscape changes and in particular forest landscape and vegetation change in an area of Valle Cannobina. To carry out such a study it is necessary to provide information about the past situation and to compare them in different years. Digital analysis of multitemporal aerial images for forest and landscape change detection has been already carried out in some studies (Ciolli and Zatelli 1999) by comparing panchromatic aerial photographs taken in different years.

The features of the images available in the practice are often very diversified because the sensing techniques have evolved through the years. So it happens that sometimes panchromatic photographs must be compared to colour photographs or Infra-Red images. This situation will be very common and this study aims to be an example that can be reproduced in any other similar situation.

In the present study the available material is very heterogeneous: aerial photographs taken in different years ('54, '77, '86, '96) are panchromatic, colour images and Infra-Red images in false colour. Aerial photographs and digital cartography have been provided by Comunità Montana della Valle Cannobina (isolines and other basic features) and RDM professional (vegetation map).

Aerial photographs represent important tools to investigate past landscape forms; they can provide information that cannot be found in satellite images that are too recent to be used for this purpose.

2. Orthorectification

The first step to be accomplished for this kind of analysis is the orthorectification of the image.

This process transforms the image in a central projection and register it in the reference system in use in one step. It is therefore now possible to carry out effective cross comparisons both metric and cartographic.

Aerial colour photographs have been scanned with an A3 scanner at 600 dpi, 24 bits. This value has been chosen because guarantees a good colour quality and a high geometric definition while the image files are still manageable in terms of bytes (90 mb). Panchromatic photographs have been taken from a higher altitude than the colour ones and therefore they have been scanned at 800 dpi to provide a comparable size of the pixels on the ground. IR photographs have been scanned with a special scanner for IR images. Scanned images have been imported in TIFF format (Tagged Image File Format). The files have been managed with an open source free software digital image manipulation system (GIMP).

TABLE 1: Examples of different aerial photographs used in this work. The medium image scale is the ratio between the medium flight height over the ground and the camera focal length. (1) Not readable on the height meter.

Photo	Type	Date	Hour	Height (m)	Focal lenght	Medium image scale
3901	Panchromatic	16-09-1954	10.22	9300	153,16	1:56000
3360	Colour	27-06-1977	12.21	3640	151,79	1:18000
3364	Colour	27-06-1977	12.22	3630	151,79	1:18000
159	Colour	01-10-1986	13.25	2620	153,33	1:12000
179	Colour	01-10-1986	13.38	2605	153,33	1:11000
1042	IR	03-09-1996	10.42	(1)	153,20	1:16000
1099	IR	03-09-1996	11.07	(1)	153,20	1:16000

Orthorectification has been carried out with GRASS GIS, an Open source free Geographic Information System which is becoming increasingly used all over the world (Ciolli, 1999, Ciolli and Zatelli 1999). GRASS is a powerful tool to manage Geographic Information, particularly for environmental studies, and includes many professional components like orthorectification modules, hydrological models, solar illumination and many others (see http://grass.itc.it). A description of the orthorectification procedure used in GRASS can be found at the address http://grass.itc.it/gdb/html_grass5/html/i.ortho.photo.html.

Orthorectification quality has been tested under the supervision of the laboratory of Photogrammetry of the Trento University.

The orthorectified photographs have been analysed with the image analysis modules. Different procedures for image classification have been used to exploit the maximum degree of information.

3. Image Analysis

Before the actual image classification some ground truth information must be available to allow a check of the results. This can be difficult when the images date back many years: often no other information is available and it is nearly impossible to reconstruct the old situation from the current conditions. As an additional source of information, several people living or working in the area at the time the images was taken had been interviewed.

The choice of the different vegetation categories to be recognised by the classification tools in GRASS is the result of a tradeoff between what classes have been ranked as important and is clearly distinguishable from a human operator and the effective number of classes the automatic procedure has been able to discriminate. The purpose of this work is to create a vegetation map, while all the other coverage types, such as buildings, roads, rocks and so on, have been grouped in one category, labelled as "other".

Three main classes have been established for the vegetation: grass, ferns and forest. The first class "grass" consists of all the grass covered surfaces as well as farming and meadows; the second class "fern", which is copious in the Valle Cannobina (AAVV 1996), includes all the areas covered with ferns and junipers; finally the third class "forest" collects all the areas covered with trees, dense or sparse. Except where otherwise specified, all the results of the application of classification techniques to the images will result in these three classes.

Two different approaches to automatic image classification are available in GRASS: unsupervised and supervised classification.

Unsupervised classification is a segmentation techniques that automatically divides the image in areas that can be regarded as homogeneous according to some predefined criteria. The operator does not instruct the program about the spectral signatures of the classes to be recognized in the image. Two different command are used in GRASS to perform an unsupervised classification: i.cluster, which forms the initial clusters and determines their statistical parameters, and i.maxlik, which classifies the whole image via the maximum likelihood criterion, using the results of the i.cluster module as input parameters.

This technique has performed poorly on the available images, especially if compared with the supervised technique, therefore it has been dropped.

The supervised classification technique relies on the a priori training of the classifier by an operator on a training map containing samples of the interesting classes: in this way the spectral signature of each class is made available to the classifier and each class is already correctly labelled. In GRASS the supervised classification process is accomplished in two stages: in the first stage the spectral signatures of all the interesting classes are evaluated on a training map, in the second step the whole image is classified according to the spectral signatures made available from the previous step. The GRASS modules performing this two step procedure are i.class or i.gensig and i.maxlik.

Moreover, it is possible to achieve a contextual supervised classification, i.e. a classification which takes into account not only the radiometric features of a single pixel, but also the properties of its neighbours and their relations. In GRASS the i.gensigset and i.smap modules perform contextual classification, the first module builds the spectral signature, while the second one classifies the image.

Tests have been carried out to determine the best classifier for the available images and the latter contextual supervised classification techniques has achieved the best performance. It has therefore been adopted for the classification of all the multiband images.

The techniques above can be applied to mutiband images, while for panchromatic images other classification techniques, based on the grey levels distribution, have been used. While these techniques have made available a coarse classification of the panchromatic images into the four classes, a further differentiation in the "forest" category was not possible.

Colour images have provided reliable vegetation maps, however the availability of images of the same area in different seasons could significantly enhance these results.

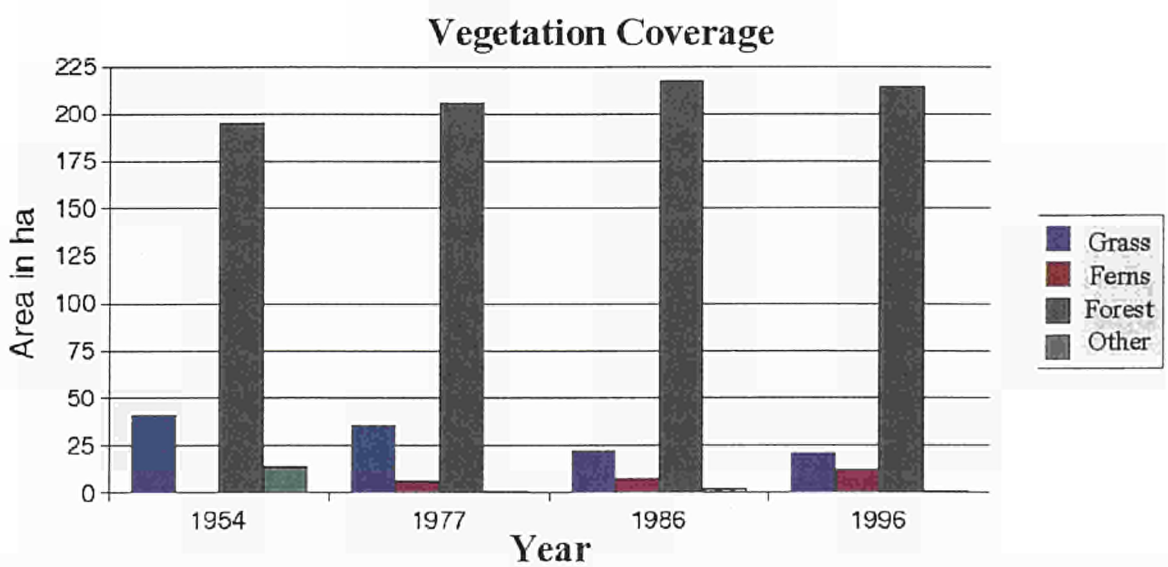

FIGURE 1: Monti di Rodè: Grass, Ferns, Forest and Other classes through the years 1954, 1977, 1986 and 1996.

While the atmospheric disturbance is probably one of the most influencing factor for the colour images, infra-red images have most likely suffered from an inadequate scanning resolution.

Two different areas of the Valle Cannobina have been analysed, since their situation and evolution with respect to the vegetation are different: Monti di Rodè and Monte Vecchio.
For the Monti di Rodè area, from the bar chart in figure 1, an expansion of the forest of about 20 hectares is manifest from year 1954 to year 1996, with the maximum expansion rate around year 1986. However, the forest coverage in 1986 is probably overestimated, due to difficulties in the image classification, so that a regular augmentation rate of the forest would most likely depict the actual trend.

This means that the forest is slowly but steadily expanding (0.5 hectares per year over the whole period). On the whole Valle Cannobina the forest expansion rate over the last 45 years is considerably higher: by applying this rate to the Monti di Rodè area an growth of 1.3 hectares per year would be expected, therefore in this area the forest is not capable of spreading out as it is in other part of the valley.

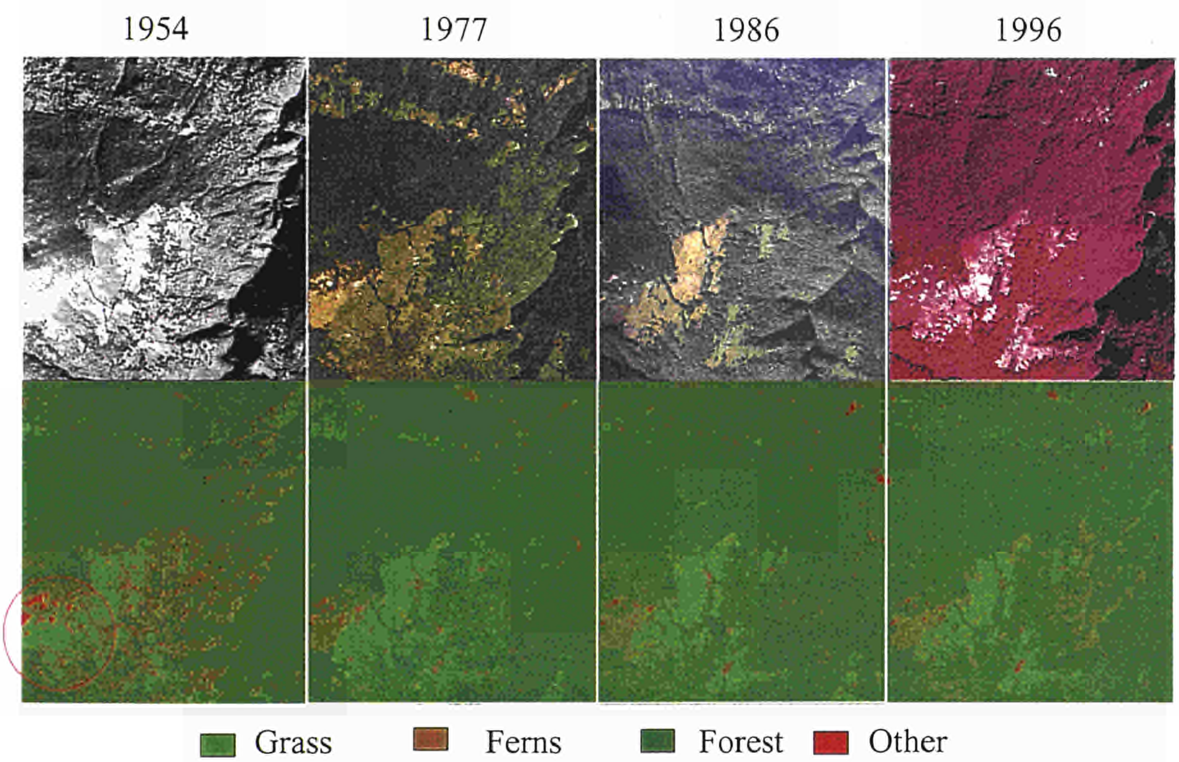

FIGURE 2 Monti di Rodè vegetation maps obtained with supervised classification.

The reason behind this is probably that while in this area the anthrophic pressure is now absent and the farming has disappeared, the breeding of sheeps and goats is still there.
Up to 500 sheeps grazed in this area until a few years ago: their number has now decreased but goats, whose feeding habits can significantly limit forest expansion, are now present.
Since the "fern" and "other" classes have not undergone significant changes, the forest expansion has shrunken the "grass" category.

The "grass" class reduction is also due to the vast expansion of the "fern" class (which includes ferns and junipers): this coverage type seems to experience an accelerated expansion over the "grass" class, most likely because it is not blocked by anthrophic activities and breeding. Variation of the "other" class are negligible and mostly due to classification uncertainty.

The second area, Monte Vecchio, has undergone the same kind of analysis of the Monti di Rodè region.

In the chart in figure 4 two different trends are visible: a large expansion of the "forest" class and a shrinkage of the "fern" and "grass" classes. The variations of the "other" class are not meaningful and the anomalous value for the year 1954 is due to misclassification. In this area the 1954 image presents classification problems for all the classes.

The above cautions standing, it is possible to affirm that in the Monte Vecchio area the "forest" class shows a significant expansion, which doubled its surface with an expansion rate of about 2 hectares per year while a rate of 1 hectare per year was expected.

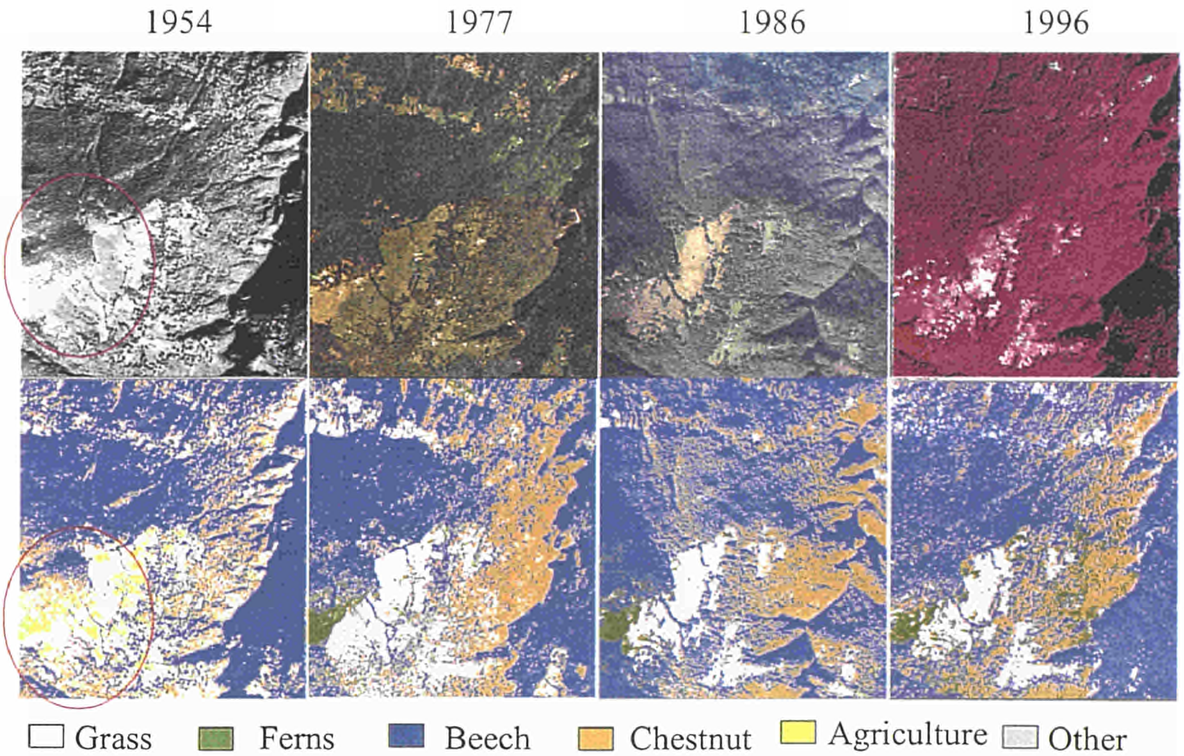

FIGURE 3 Monti di Rodè: vegetation maps obtained with supervised classification.

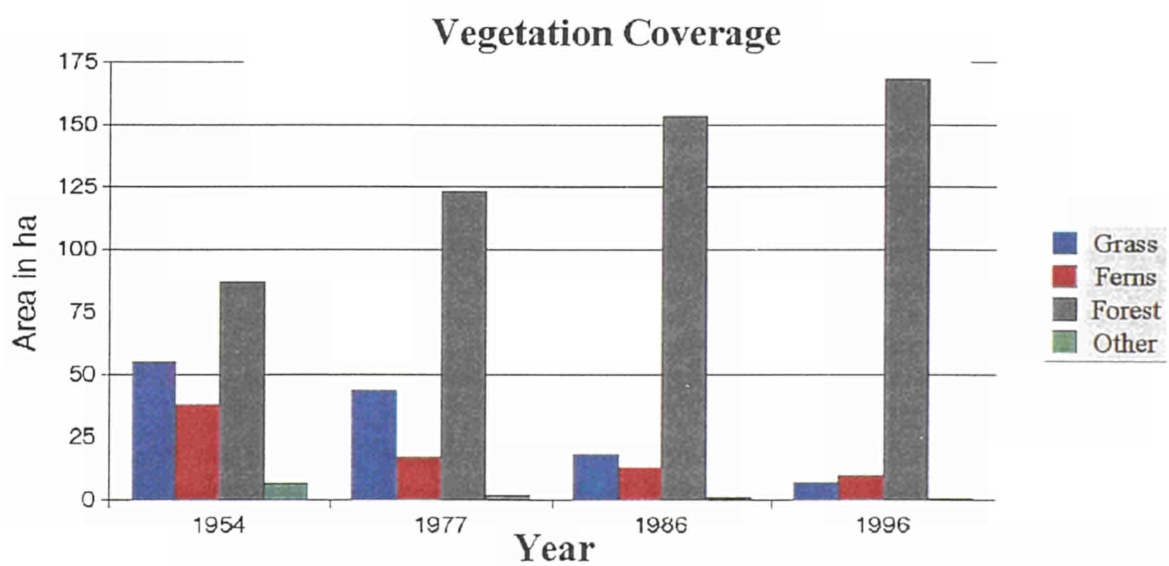

FIGURE 4:
Monte Vecchio: Grass, Ferns, Forest, Other through the years 1954, 1977, 1986 and 1996

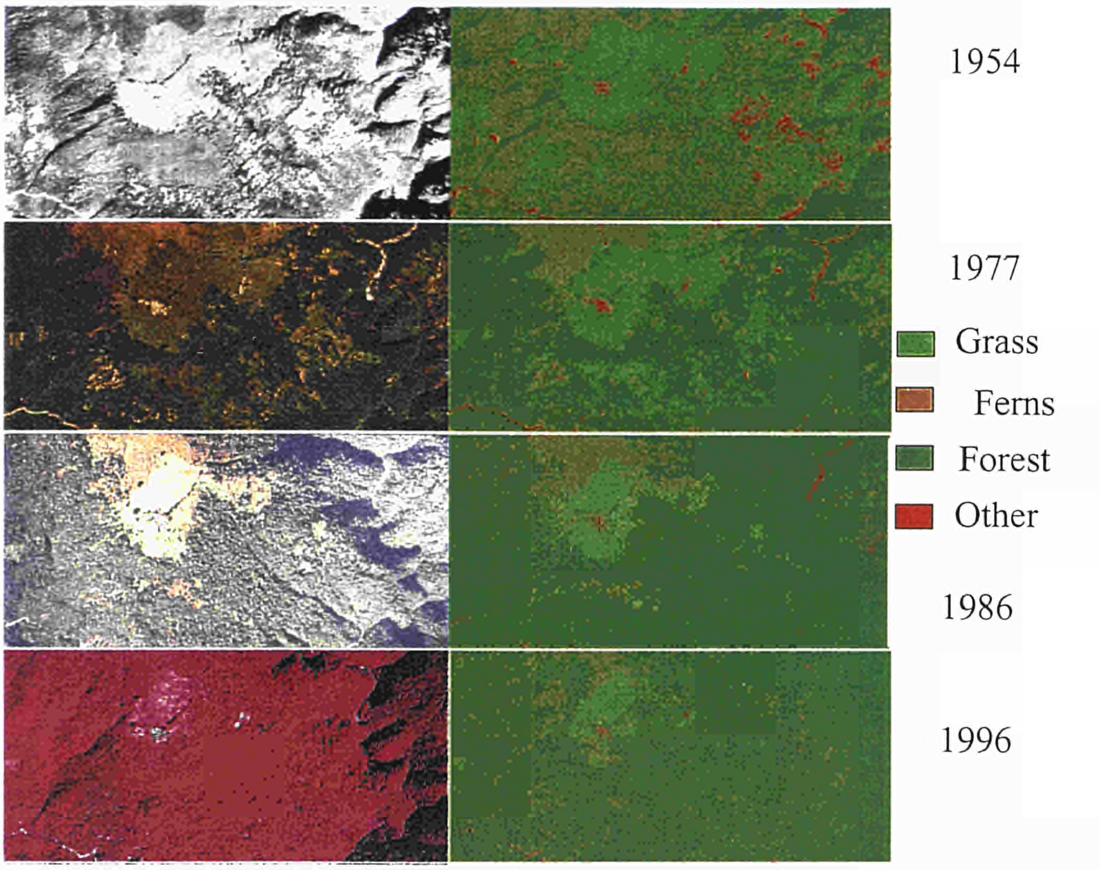

FIGURE 5. Monte Vecchio vegetation map obtained with supervised classification

Extremely meaningful is the grass reduction: this coverage class is disappearing and the last clusters are now being taken over by birchs, beechs, ferns, genistras and orther species, arboreous or shrub, as a survey on the ground has shown.

The trend of the "fern" class here is different from the one for the Monti di Rodè area: this coverage type is reducing even if ferns are taking over the grass because of the competition of the forest.

Using GRASS it has been possible to evaluate the surface of the areas which changed from "grass" to "fern" and from "fern" to "forest" over the years (TABLE 2).

TABLE 2: "grass" class surface taken over by "fern" and "fern" taken over by "forest".

	From "grass" to "fern" (ha)	From "fern" to "forest" (ha)
From '54 to '77	4,997	27,575
From '77 to '86	4,790	8,151
From'86 to '96	1,799	9,300

Even with the necessary caution, the invasion of the "forest" class over the "fern" is larger than that of the "fern" class over the "grass".

Therefore, it is possible to assume that, if no external factor, anthrophic or natural such as wildfires, will occur, in less than 20 years all the grass and fern coverages will disappear, substituted by forest.

4. Results

Because of their importance, vegetation maps have been created using different procedures to automatically classify aerial images exploiting GRASS GIS image analysis capability.

As a first stage all the available techniques have been tested on the colour image n.159 of the 1986: the contextual supervised classification procedure provided by the i.gensigset and i.smap has given the best results, especially when the samples used to build the spectral signatures have been randomised so that good descriptions of the classes are possible even using limited size samples and therefore speeding up the procedure.

However a more specific classification inside the forest, to discriminate the different vegetation types, has been not possible, also because the lack of knowledge of the situation on ground has made difficult the preparation of good spectral signature for the different species.

This analysis shows clearly the tendency of the forest to take over all the open spaces: from 1954 and 1996 in the two areas of Monti di Rodè and Monte Vecchio the total forest expansion has been of about 100 hectares over a total of 436 hectares.

The "fern" class is present in both the areas but, while in the Monti di Rodè region it is spreading over the discarded pastures and reached the extension of more than 12 hectares in 1996, in the Monte Vecchio area its total surface has reduced because the surface of ferns taken over by the forest is larger that the new area staled from the ferns to the grasses so that the overall "fern" class area has reduced from 38 to less than 10 hectares in 42 years. This different behaviour is probably due to the different growth rate of the "fern" area in the two zones (0.5 hectares per year against 2 hectares per year), tied to the presence of the breeding of sheeps and goats in the Monti di Rodè area, limiting the forest expansion.

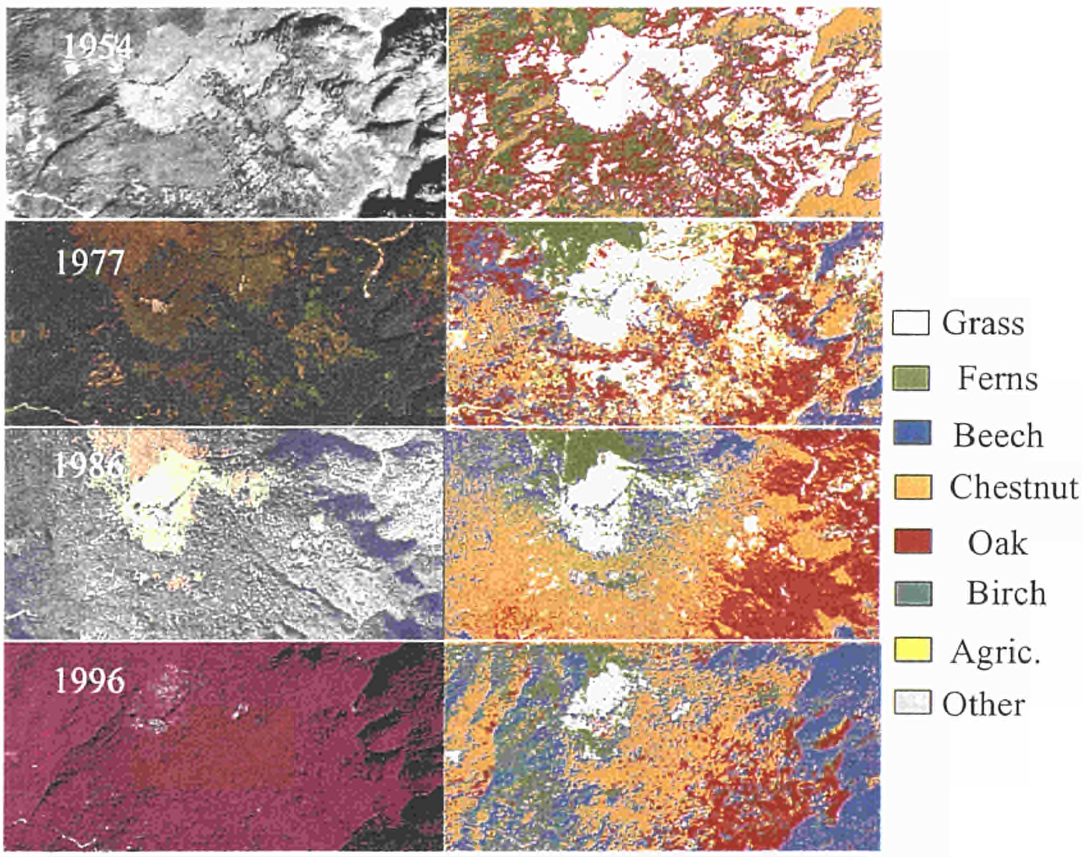

FIGURE 6 Monte Vecchio vegetation maps obtained with supervised classification

This highlights the importance of the atrophic factors on the environmental changes even when the human presence recedes. Infect, while in the Monte Vecchio region in a few years the forest will cover the whole area reaching a natural equilibrium, in the Monti di Rodè zone the atrophic factors, even the actual lack of human presence, slow the natural evolution of the ecosystem toward an equilibrium.

The choice of the two different test areas has provided a way to emphasize the human role in the natural dynamics of mountain areas.

Further studies are need for the classification of the vegetation, in particular: the use of vegetation indexes and image texture and the optimisation of the choice of the right GRASS modules and their fine tuning. Additional inquiries have to be done about the image enhancement techniques (using GRASS modules or other systems) to help the classifier to exploit all the available information from the images, in particular for the shadowy zones of the images.

A survey on the field to provide more accurate and more numerous sample area for training the supervised classifiers would offer a way to gain an overall better classification precision and the possibility to discriminate between more vegetation classes, even inside forest areas.

5. Conclusions

By the use of GRASS modules photogrammetric and clustering analysis have been carried out to evaluate both in a qualitative and in a quantitative way the landscape and coverage changes in test areas.

It has therefore been possible the description of the changes under way in these areas, changes that are common to all the mountain areas in the last 50 years, mostly due to the deficit of population of the alpine regions which results in the loss of the previous ecological equilibrium.

Moreover, this work has investigated the ability of the GRASS GIS to manage such a heterogeneous photographic material, in particular for its registration and automatic classification to provide multitemporal thematic maps depicting the land evolution over more than 50 years.

References

AA.VV. 1996. Carta della vegetazione della Valle Cannobina. Studio RDM: Firenze.

Bouman, C.A., Shapiro, M. 1992. Multispectral Image Segmentation using a Multiscale image Model. Proc. of IEEE Int'l Conf. on Acoust., Speech and Signal Proc., pp. III-565 - III-568, San Francisco, California, March 23-26.

Bouman, C.A., Shapiro, M. 1994. A Multiscale Random Field Model for Bayesian Image Segmentation. IEEE Transactions on Image Processing, 3(2):162-177.

Cantiani, M. G. 1999 - Piano Ecologico-Territoriale della Valle Cannobina (V.C.O.). Trento.

Ciolli, M. 1999. GRASS GIS: Uno strumento di supporto alla pianificazione forestale. *In* Atti del II° Congresso della Società Italiana di Selvicoltura ed Ecologia Forestale (S.I.S.E.F.) Applicazioni e Prospettive per la Ricerca Forestale Italiana, pp.167-173. Bologna.

Ciolli, M., Mascarell Pavìa, B., Sguerso, D., Zatelli, P. 1999 - Valutazione tramite fotogrammetria e GIS della dinamica della copertura forestale e della provvigione legnosa. *In* Atti della 3a Conferenza nazionale delle Associazioni Scientifiche per le informazioni Territoriali ed Ambientali, pp 589-594. Napoli, Vol 1.

Ciolli, M., Menel Lemos, G.T., Zatelli, P. 2001. Sperimentazione di modelli di colore nella classificazione automatica di foto a colori. *In* Atti del convegno "5a Conferenza nazionale delle Associazioni Scientifiche per le Informazioni Territoriali ed Ambientali", pp. 553-558. Rimini, 9-12 ottobre, 2001. ASITA: Rimini, Vol. 1.

Ciolli, M., Zatelli, P. 1999. Automatic forest area recognition using GIS image analysis capability. International archives of photogrammetry and remote sensing, vol. XXXII, part 6W7, pp. 163-168.

D'Angelo M., Galli A., Motta M., Zucca C. 1999. Monitoraggio delle risorse forestali in ambiente mediterraneo mediante telerilevamento. *In* Atti del II° Congresso della Società Italiana di Selvicoltura ed Ecologia Forestale (S.I.S.E.F.) Applicazioni e Prospettive per la Ricerca Forestale Italiana, pp.183-188. Bologna, 20-22 Ottobre 1999.

Donatelli, R. 1996. Il paesaggio alpino in trasformazione. Riorganizzazione e conservazione del sistema di alpeggi in Valle Cannobina. Tesi di laurea. Politecnico di Milano Facoltà di Architettura, anno accademico 1996-97.

Ingegnoli, V., Pignatti, S. 1996. L'Ecologia del Paesaggio in Italia. CittàStudiEdizioni di UTET Libreria srl: Milano.

Menegon, S. 1998. Metodologie GIS per la valutazione predittiva dei miglioramenti ambientali su piccola scala. Tesi di laurea. Università degli studi di Trento Facoltà di Ingegneria, anno accademico 1998-99.

DETERMINATION OF TREE DIAMETER-AT-BREAST-HEIGHT AND VOLUME FROM CROWN SIZE

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Abstract

In this paper a method for remote determination of tree DBH and volume is described. A fifth order polynomial equation for predicting DBH from crown projection area was fitted using ground measurements of 3,470 Scots pine trees from seven different stands. The model explains 91% of DBH variability. Accuracy and precision of predictions were examined for each stand. In older stands DBH was predicted with high accuracy (average error from 3 to 7%); for younger stands average error reached 30%. DBH calculated from the proposed model was used to predict total and merchantable stem volume from existing equations. Volume of the older stands was predicted with high accuracy (average error less then 10%). The accuracy for younger stands was lower. The proposed method can be used with large-scale aerial photographs (up to 1:10,000) where number of trees and area of the crown projection (for a single tree or group of trees) can be measured.

Keywords: DBH, volume, crown, aerial photogrammetry

I have a dream...
(from the song of ABBA)

1. Introduction

In the middle of previous century a well known American forester Stephen H. Spurr stated: "...remote sensing was promising in forestry mapping and inventory..." (Spurr 1952). It was his evaluation of the place of remote sensing and it's importance in forest inventory at that time. Now we can say: yes, it was promising, it is promising and it will be promising. Promising,... promising and giving not only in forest inventory but in forestry, and more generally in environmental sciences as well.

What exactly does remote sensing promise to foresters? Among the hopes and dreams of many foresters it is still present one, which could be described as following: everything could be evaluated from the satellite imagery or aerial photographs. No dull, no exhausting and boring ground measurements in the middle of hostile forest - all we need is the septic, air conditioned GIS lab, with powerful computers armed in programs and peripherals. In that position they can answer to any questions on forest management, protection, harvesting, silviculture, forest policy, carbon sequestration etc, etc...

It is a dream, but a nice one. And, in a big part, due to work of the people like you, it comes through... But before such dreams are "coming through" a lot of work has to be done. First of all, behind all models or empirical equations, a lot of experimental data collected in the field must exist. The credibility of prognosis of a model depends heavily on quality and quantity of collected observations. Such observations could be gathered in both ways: by field measurements "on the ground" and by observations done "from above" (aerial, satellite).

This paper deals with ground-measured data, but authors hope that results can be referred to observations registered in large-scale aerial photographs. Both authors are not "remote sensing people", they are rather "full contact foresters". We know a lot about field measurements, about forest survey, but our knowledge about remote sensing is based mostly on studying papers published by other people, attending to seminars (like ROGOW 1999) or discussing with friends who deal with GPS, GIS, LANDSAT TM or with other fancy names. In this way it is no a surprise, that we have been looking for "useful hints" in previous works. We found a lot of them, but for the reason of scarcity of the pages given to any attendant of our seminar, we will name only a few.

In span of seventeen years, data describing size of tree crowns in Scots pine stands have been collected at the Faculty of Forestry of Warsaw Agricultural University. All trees with measured crowns were also the subjects of very detailed measurements after felling. Despite the long period of investigation, the methodology of work was still the same. Altogether it was about 3,500 trees measured in different stands. We felt that such material can enrich our knowledge about relationship between size of the crown and tree thickness and volume. Behind such relation is the simple rule: "the bigger factory has bigger yield". In this case "the factory" denotes green leaves/needless active in the process of photosynthesis which quantity is depicted by size of the crown. "The yield" is the net accumulation of organic matter in trunks, branches and roots.

The exploiting this relationship in determination of DBH or volume from aerial photographs has quite long history. In 1961 Furnival elaborated non-linear model in which DBH of tree relays on crown diameter (Furnival 1961). Aldred and Kippen estimated DBH from product of tree height and area of crown using very large scale photographs (1:1,200) a few years later (Aldred and Kippen 1967). Paine and McCadden established regression between ground measured stem variables and the crown measurement on photographs with scale 1:3,500 (Paine and McCadden 1988). Hagan and Smith were investigating relation between diameter at groundline (stump diameter) and the area of crown instead of DBH. Leech after investigating open-grown radiata pine stated that crown width is linearly related to tree DBH (Leech 1984). This relationship was independent of site quality. Akca (Akca 1984) was going so far, that he was trying to estimate increment with help of the crown diameter measured on photographs.
After consideration all what was said above, we would try to answer to the following questions:

- how strong is the relationship between DBH of a tree and its crown projection area (CPA) in pine stands?
- how accurate will be the model predicting DBH from CPA?
- will be it possible to predict DBH of a single tree or average DBH for a group of trees?
- will the model work well independently of age and site quality?

Some of these questions seem to be rhetoric, but even approving the result of earlier works will be important for the reason of the size of our empirical material. At last, we will demonstrate and evaluate how the empirical equations for calculation the volume, will cooperate with DBH predicted from the model.

2. Empirical material

Ground measurements were collected in seven Scots pine stands located in big forest complexes of Poland. The stands were from 29 to 95 years old. Sample plots with size from 0,12 – 1,50 ha were established in these stands. Some basic information for experimental plots is given in Table. 1

TABLE 1: Description of experimental plots

PLOT'S LABEL	MEAN AGE [yrs]	PLOT AREA [ha]	NUMBER OF TREES PER PLOT	NUMBER OF TREES PER HECTAR	SITE INDEX* [m]	TYPE OF SITE**	AVERAGE DBH [cm]	AVERAGE HEIGHT [m]
PA	29	0,12	646	5333	28	FCMF	8,3	10,5
PN	44	0,36	805	2233	21	FCF	13,1	13,3
BD	51	0,36	535	1508	21	FCF	14,9	14,6
R48	80	1,50	508	357	28	MBF	34,0	24,7
R10	89	0,75	259	339	29	MBF	38,8	26,9
PP	94	1,31	507	390	27	FCF	30,8	25,5
R9	95	0,75	211	272	28	MBF	41,7	26,3

* Top height of the stand in the age of 100 years

**FCMF – fresh conifer mixed forest
FCF – fresh conifer forest
MBF – mixed broad-leaved forest

Altogether there were almost 3,5 thousands of trees measured. All trees were numbered and diameter at breast height (DBH) was measured and recorded as rounded to the nearest milimeter. The crown radius of each tree was measured in eight directions (N, NE, E, SE, etc) with specially elaborated techniques and equipment described by Dudek and Borowski (Dudek 1969; Borowski 1974). Crown projection area (CPA) of each tree was calculated as area of an octagon. After that all trees were cut-down and, among others, measurements for sectional Huber's formulae were taken from them. Volume of each stem outside-bark (VSTEM) and merchantable stem volume outside bark (VMERCH) were calculated. Results of CPA measured in different stands are briefly presented in Tab. 2, Fig.1 and Fig.2.

TABLE 2. Crown projection area (CPA) on different plots

PLOT'S LABEL	MEAN CPA $[m^2]$	MIN CPA $[m^2]$	MAX CPA $[m^2]$	CV of CPA [%]	CROWN COVER FRACTION [%]
PA	1,54	0,05	9,00	78	0,83
PN	2,29	0,20	9,90	66	0,51
BD	3,70	0,10	13,10	64	0,55
R48	17,19	1,90	63,20	54	0,58
R10	20,02	2,20	64,00	57	0,69
PP	14,31	3,30	53,00	47	0,55
R9	23,62	1,40	66,10	49	0,66

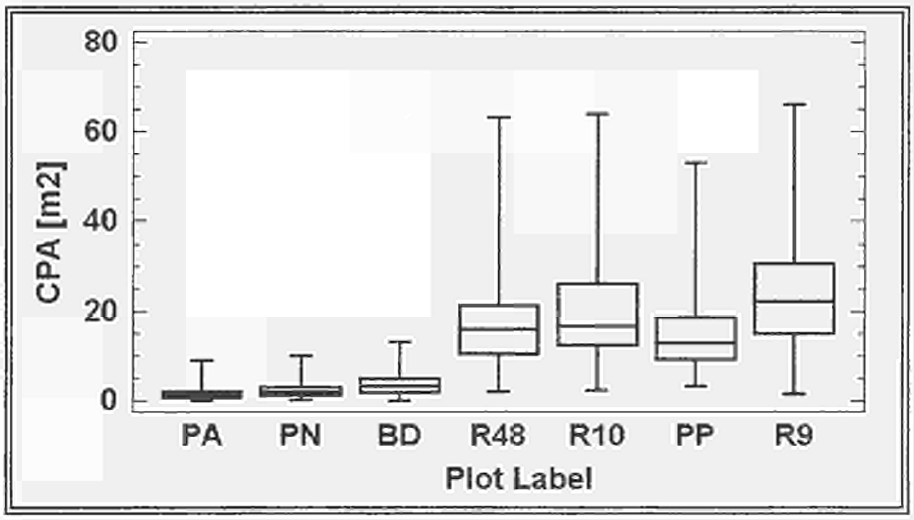


FIGURE 1. Crown Projection Area – Box-and-Whisker-Plot

Size of the crown strongly depends on the age of the stands. CPA distributions are positively skewed in all stands. Variability of CPA is very high. Its coefficient of variation (CV) value varies from 50 to 80 percent.

3. PREDICTION OF DBH FROM CROWN PROJECTION AREA

Both variables are "ground measured", we assumed, that the difference between CPA measured on ground and on the photograps will be acceptable. We hope that due to big number of measured trees we can predict DBH with high accuracy. Before elaborating of this function we have been wondering: which crown characteristic could be more useful in this case? The reason that we selected crown projection area was the existing of better-developed techniques of automatic measuring the crown area on aerial photographs (H. Olenderek, personal communication).

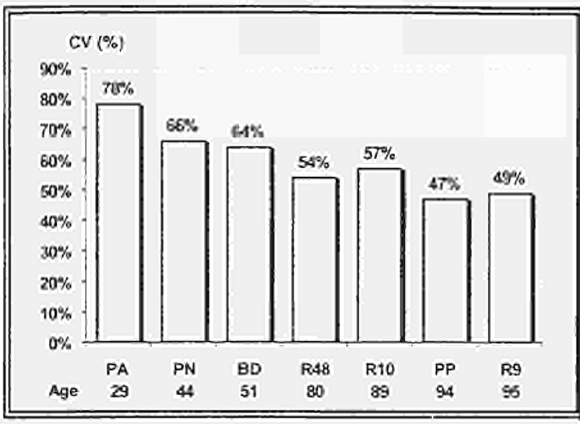


FIGURE 2. Coefficient of variation of CPA

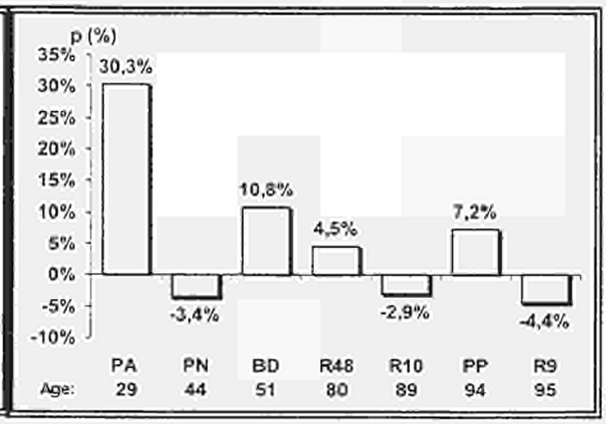


FIGURE 3. Errors of DBH when predicted from the model

A fifth order polynomial equation was chosen as the model for predicting DBH from the crown projection area. Model parameters were calculated using the least-squares method with Statgraphics Plus for Windows 4.0 statistical package. The final form of the model is given below:

$$DBH = 5{,}498 + 3{,}34542 \cdot CPA - 0{,}143456 \cdot CPA^2 + 0{,}00352034 \cdot CPA^3 - 0{,}0000427104 \cdot CPA^4 + 2{,}01744E\text{-}7 \cdot CPA^5 \quad [1]$$

The model explains 91,15% of the variability of DBH (R-squared, adjusted). Standard error of estimate (standard deviation of residuals) amounts 3,73 cm. Elaborated model may be used for predicting DBH from the size of crown (CPA) which can be estimated from aerial photographs of pine stands.

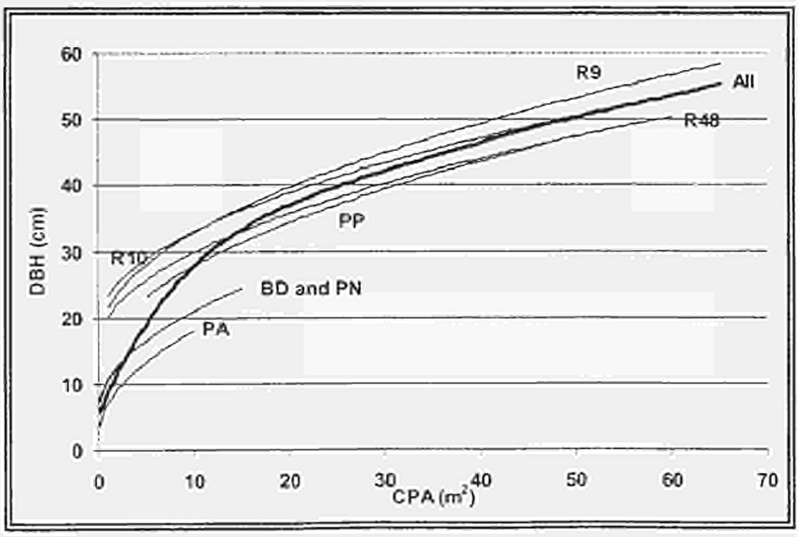
4. Model evaluation

We examined two ways of the model using: predicting average DBH for the stand (from average CPA) or predicting DBH of single trees from their CPA. We assumed that differences between CPA measured on ground and from photo image would be not significant.

Errors of DBH prediction when for each stand the value of DBH is calculated from the model using the average CPA for stand as the input are demonstrated on Fig.3. Generally accuracy of prediction for older stands is higher. The standard error of estimate for this model is 3,73 cm, so it is no surprise, that for stands with small average DBH errors expressed in percents are big.

Conclusion could be taken from Fig.4, where fitted lines for each of seven stands and the model for whole material are demonstrated. Separate models for old and young stands can improve results of predictions.

FIGURE 4. Relationship between DBH and CPA



Accuracy and precision of prediction the single tree DBH are summarised in Tab.3. Prediction errors can be very large when predicted is single tree's DBH. The range of errors is very broad. So it is very risky to use the proposed model for a single tree. From standard deviation values (vary approximately from 11 to 19%) we can calculate also standard deviation for the sample with any size. For example, precision of prediction for the sample of 50 trees will be between 1,5-3%.

TABLE 3. The accuracy and precision of DBH prediction for single trees

PLOT'S LABEL	PERCENTAGE ERROR			STANDARD DEVIATION OF ERRORS
	MEAN	MAX.	MIN.	
PA	30,1	100,4	-10,8	18,5
PN	-5,9	48,6	-46,0	16,8
BD	5,4	57,3	-46,5	19,8
R48	-1,7	46,8	-62,3	14,3
R10	-8,2	31,1	-65,1	14,7
PP	2,9	64,3	-43,5	13,4
R9	-8,4	26,8	-63,7	11,6

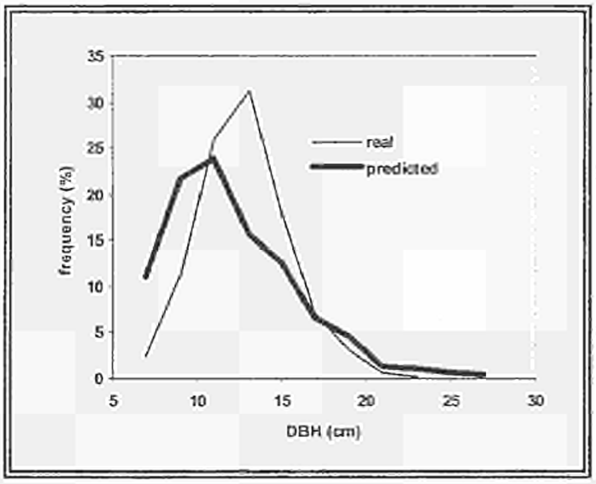


FIGURE 5. Comparison of distributions of real DBH and DBH predicted from the model – - PN plot

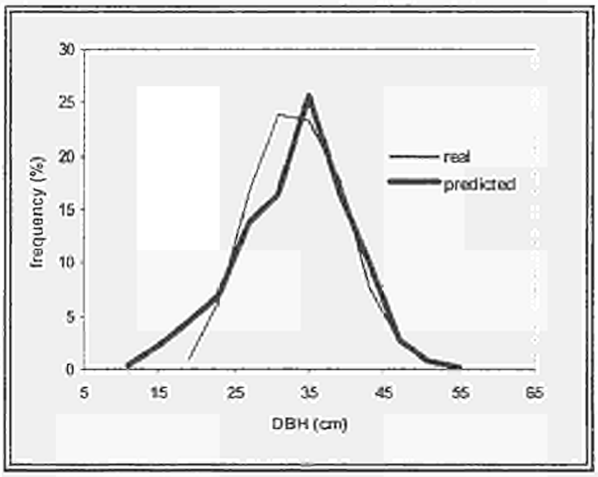


FIGURE 6. Comparison of distributions of real DBH and DBH predicted from the model – - R48 plot

On the Fig. 5 and 6, as an example, real distributions of DBH and the distribution predicted by model in two different stands are compared. In both cases the model predicts little higher range of DBH, but generally the shape of distributions is quite similar.

5. ESTIMATING THE VOLUME FROM PREDICTED DBH

It is possible to estimate an average tree volume in a stand or volume of a particular tree using DBH value predicted by the model. Calculations of the stem volume over bark (VSTEM) or merchantable stem volume over bark (VMERCH) for DBH predicted by the model was done with species-specific empirical formulas elaborated for Polish forests (Bruchwald et al. 2000; Bruchwald et al. 2001). These equations allows to calculate volume of 18 different tree species from the tree's DBH and it's height ranked in five classes (very low, low, average, high, very high). We assumed an average height of trees/stands in all calculations. Enriching information with the height measured from photo images will improve result.

Errors of VSTEM calculated when the model predicts DBH after using the average CPA for stand as an input are demonstrated on Fig. 7. As mentioned above, further calculations (from predicted DBH to VSTEM) were done with the help of the empirical formulas. Accuracy of volume determination for old stands is higher than in younger stands. Errors of similar calculations for merchantable stem volume are presented on Fig. 8.

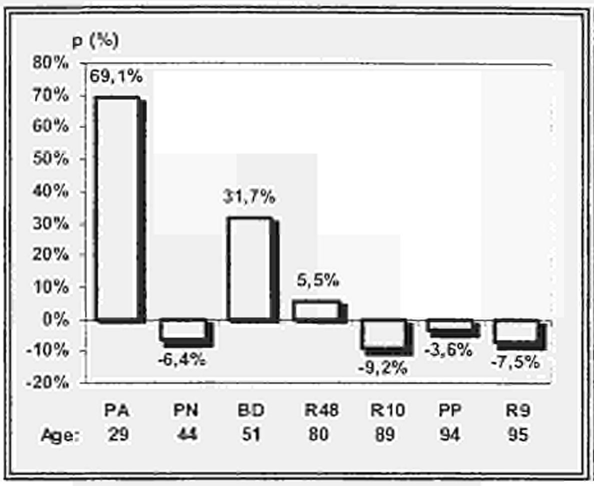


FIGURE 7. Errors of VSTEM calculated with proposed method

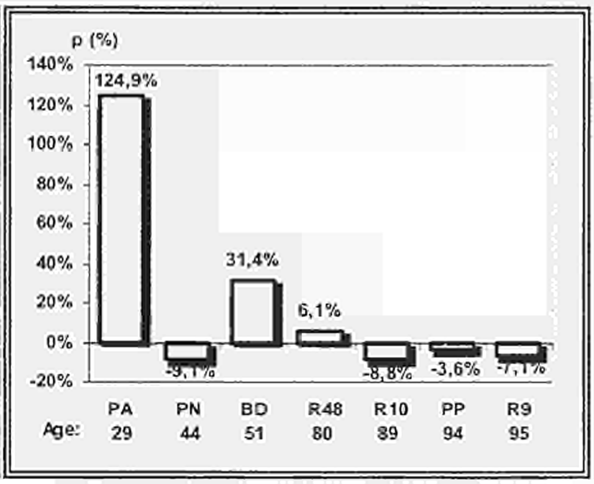


FIGURE 8. Errors of VMERCH calculated with proposed method

As before, results for old stands can be acceptable. The error for the youngest stand (PA) is not big, the error for this stand is just huge. The reason is because of the definition of the merchantable volume in Polish forestry. The merchantable volume means the volume of this part of a tree, which diameter over bark is bigger than 7 cm. The stand PA is 29 years old. This kind of volume just arises at this age. Some trees are without of such volume, some are with it. At this stage of stand's development the prediction of VMERCH is very difficult. Table 4 presents the results of estimation of VSTEM and VMERCH for single trees.

TABLE 4. The accuracy and precision of VSTEM and VMERCH prediction for single trees

PLOT'S LABEL	VSTEM				VMERCH			
	PERCENTAGE ERROR			STANDARD DEVIATION OF ERRORS	PERCENTAGE ERROR			STANDARD DEVIATION OF ERRORS
	MEAN	MAX	MIN		MEAN	MAX	MIN	
PA	90,3	444,2	-26,6	69,1				
PN	-2,2	231,7	-71,5	45,9				
BD	32,7	268,7	-75,5	63,0				
R48	-2,1	105,1	-91,9	30,0	-1,6	108,4	-93,1	30,8
R10	-14,3	114,4	-92,5	28,9	-14,0	117,8	-93,4	29,7
PP	-7,1	164,1	-77,5	28,5	-6,8	170,4	-79,0	29,2
R9	-11,0	83,1	-89,5	23,0	-10,6	85,3	-91,7	23,6

Accuracy of VSTEM calculating expressed as mean percentage error. As before, it is good for old stands. Precision of estimation for a single tree is not very high. Precision for the sample consisting of 50 trees will be in limits of 3-10%. We did not calculate VMERCH for individual trees from young stands, so the right half of the Tab. 4 is blank in first three rows. Predicting values of VMERCH for old stands bring satisfying results.
Distributions of VSTEM real versus predicted on the example of two stands are compared on Fig. 9 and Fig. 10. The distributions are very similar in old stand. Distribution „predicted" is a little „shifted" to the right. Predicting of the VSTEM distribution in the young stand (PN) by the proposed methods brought rather poor result. Predicted distribution has bigger range, the right tail reaches the value close to 0,6 m^3, compared to 0,3 for the real VSTEM.

Comparing the distributions of VMERCH (real versus predicted) shows up satisfactory results (Fig. 11). Tendency is similar to previous cases: small movement of predicted distributions in the direction of bigger values, predicted range is a bit bigger than real.

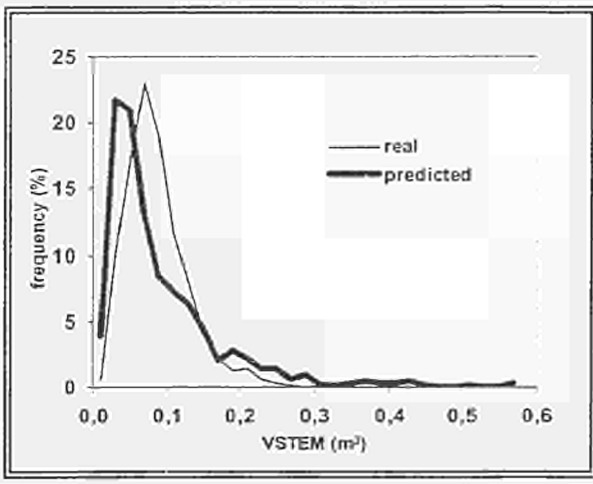


FIGURE 9. Comparison of distributions of real VSTEM and VSTEM predicted from the model - PN plot

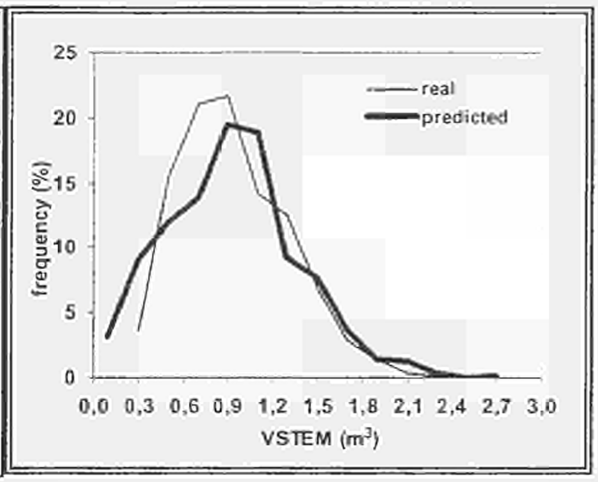


FIGURE 10. Comparison of distributions of real VSTEM and VSTEM predicted from the model - R48 plot

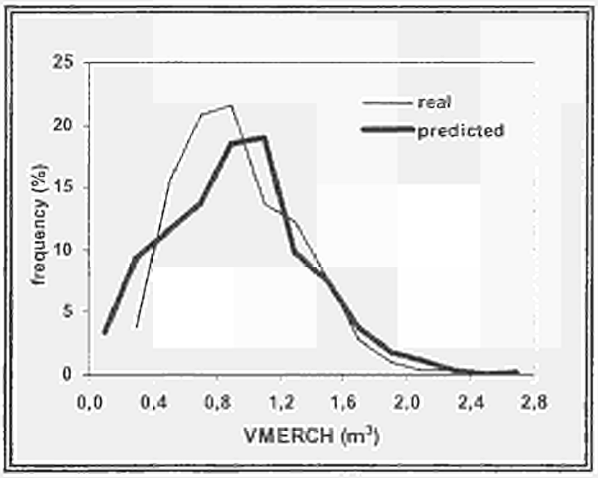


FIGURE 11. Comparison of distributions of real VMERCH and VMERCH predicted from the model - R48 plot

6. CONCLUSIONS

In pine stands, diameter-at-breast-height strongly correlates to crown projection area (R-squared 91,1%). This relationship was exploited for constructing the model used for predicting the DBH of a tree or an entire stand. The model functions well in predicting the average DBH of old stands (average error from 3 to 7%). Results for young stands were not as good. A separate model for stands below the age of 60 should be elaborated on in further investigations. After examining how the model works during prediction of a single tree's DBH, how the comparison of predicted and real DBH distribution looks, and after examining the degree of variability of errors for a single tree, we do not advise predicting DBH for a single tree. The proposed model predicts DBH distribution quite well. We propose to use the described method not only to estimate DBH, but volumes as well. We tested existing empirical formulas that permit us to obtain volume or merchantable volume from only the predicted DBH value. The accuracy of results for old stands is very high (average error less than 10%). For young stands accuracy was lower. Estimation of stand volume would be better if the average height was measured on the aerial photographs.

ACKNOWLEDGEMENTS

We dedicate this paper to the forestry students and professors, the forest officers and workers, who have been gathering DATA during many winters and summers. We hope, that due to their efforts, job of foresters will be not so tough in the future.

REFERENCES

Akca, A., 1984. Zur Zuwachßchätzung mit Hilfe von Kronen messungen im Luftbild. Allgemeine Forst- und Jagd. Ztg.: 136-155, Jg., 6.

Aldred, A.H., Kippen, F.W. 1967. Plot volumes from large-scale 70-mm air photographs. Forest Science, Vol. 13, No. 4, Dec.: 419-425.

Borowski, M. 1974. Przyrost drzew i drzewostanów.[The growth of trees and stands.] Państwowe Wydawnictwo Rolnicze i Leśne, Warszawa.

Bruchwald, A., Rymer-Dudzińska, T., Dudek, A., Michalak, K., Wróblewski, L., Zasada, M. 2000. Wzory empiryczne do określania wysokości i pierśnicowej liczby kształtu grubizny drzewa. [The empirical formulas for determination of height and the form factor of merchantable stem.] Sylwan, 3: 5-13.

Bruchwald, A., Rymer-Dudzińska, T., Dudek, A., Michalak, K., Wróblewski, L., Zasada, M., Tomusiak, R. 2001. Tablice służące do określania pierśnicy i miąższości drzewa na podstawie średnicy pniaka. [The tables for determination DBH and tree volume from stump diameter.] Centrum Informacyjne Lasów Państwowych, Warszawa. ISBN 83-88 478-12-5.

Dudek, A. 1969. Zależność intensywności przyrostu miąższości i przyrostu piersnicy od wielkości korony. [The dependence of the intensity of volume increment and the diameter increment from the size of crown.] Folia Forestalia Polonica, seria A, 15: 149-169.

Furnival, G.M. 1961. An index for comparing equations used in constructions volume tables. Forest Science, (7) 4: 337-341.

Hagan, G.F., Smith, J.L. 1986. Predicting tree groundline diameter from crown measurements made on 35-mm aerial photography. Photogrammetric Engineering and Remote Sensing, Vol. 52, No. 5, May : 687-690.

Paine, D.A., McCadden, R.J., 1988. Simplified forest inventory using large-scale 70-mm photography and tariff tables. Photogrammetric Engineering and Remote Sensing, Vol. 54, No. 10, October: 1423-1427.

Monitoring ecological stability trough tree-ring analysis as a contribution to sustainable forest management in protected areas in Sicily

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ABSTRACT

The cessation of traditional exploitations and the lack of a proper forest management involved in Sicily the arising of vegetation dynamics, leading to changes in floristic and structural features of forest stands. Such a situation is very common in many protected areas in Sicily. In the last decades, in an aged coppice in Mt Carcaci Nature Reserve, a luxuriant development of English ivy has been observed to the detriment of the hosting downy oaks. Investigations through tree-ring analysis showed that actually, after a first phase of positive influence of ivy on the growth of oaks, a second phase of active competition probably starts, implying a progressive reduction of vitality of the host trees. According to these results, such problems should be taken into account in the future management of protected areas and a continuous monitoring of forest evolution is needed in order to maintain or improve the ecosystem stability.

Keywords: aged coppice, competition, *Hedera helix*, *Quercus pubescens*, vegetation dynamics

1. Introduction

Since the 1960s forest exploitations for fuelwood and charcoal production have been progressively ceasing in many areas of Sicily. In addition, the special protection regime or an improper management in Nature Parks and Reserves strongly limited the ordinary silvicultural practices. This involved the arising of vegetation dynamics, leading to changes in floristic and structural features of forest stands.

In a 58-years-old aged coppice dominated by downy oak (*Quercus pubescens* s.l.), English ivy (*Hedera helix* L.) exhibits such a spreading and individual development that it behaves, in the functional point of view, as a "parasite". Oaks with the crown completely wrapped by ivy are quite common and trees showing clear symptoms of decline can be often found. In order to better understand the nature of the interactions between the vine and the downy oak, an investigation through tree-ring analysis was carried out. The main goal was to gather information that could be useful in assessing the proper management guidelines in protected areas.

2. Methods

The study site is located in the Sicani Mts, Central-West Sicily (37°43'N, 13°31'E). It is included in the Mt Carcaci Nature Reserve, which was established in 1997. The landscape is hilly-mountainous, with a mean elevation of about 700 m a.s.l.. Soils are prevailingly Calcic brown soils, Vertic brown soils and Rock outcrop, lying on limestones and clays substrata. Climate is Meso-Mediterranean sub-humid, with yearly rainfalls of about 720 mm and mean annual temperature of 13.5°C.

The investigated stands are old coppices no longer exploited since at least 35-40 years. They are composed mainly by *Quercus pubescens* s.l., *Q. ilex* L., *Acer campestre* L., *Fraxinus ornus* L., *Sorbus torminalis* (L.) Crantz, *Crataegus oxyacantha* L., *Pyrus amygdaliformis* Vill., *Hedera helix* L., *Smilax aspera* L.. Except wildfires protection, no active management is presently practised in the whole area.

In order to assess the general biometric features of the stands, a sampling was carried out in two 628 m^2 plots; in the first one (QP1), most of the downy oak trees were affected by English ivy attack, whereas in the second one (QP0) almost all trees were ivy-free. In both plots, diameter at breast height (dbh) and height were measured for each stem and the intensity of ivy attack was noted according to the following criteria: *1. no attack*: the whole stem was free of vine; *2. weak attack*: the height of ivy sprouts was below the lower quarter of the trunk of the hosting tree; *3. moderate attack*: only the upper quarter of the hosting tree was free of vine; *4. strong attack*: the crown of the hosting tree was completely wrapped by ivy.

In each plot, a set of 10 dominant trees (old standards) was cut; those in QP1 were *strongly* attacked by ivy, which in its turn was cut, too. Three sets of trees were then obtained: non-host oaks, host oaks and ivy. Separated weight of trunk and branches of the three sets of trees were determined in the field. Afterwards, in all oak and ivy trees, trunk disks were taken at 1-meter intervals along the whole length of the bole and after classic preparation in the laboratory a stem analysis (Rondeux 1993) was carried out. Careful visual crossdating was needed, especially for ivy, and after tree ring measurement at 1/100 mm precision, statistic crossdating was also performed. Individual tree ring chronologies were built following the method of the *moving average of ring width among 4 contiguous sections*, from the top to the base of the trunk (Kolishchuk 1990). This approach was essential in order to establish tree ring chronologies for ivy; in the same time it gave a closer representation of the radial growth of the whole bole of each tree. The master chronologies of each population of trees resulted from the average of the ten individual curves. Finally, height growth curves were built for the three populations of trees.

3. Results And Discussion

There were slight differences in mean dbh and height of the two investigated stands, whereas quite similar values characterised the two sampled populations of oak (table 1).

In QP0, 81.6% of trees showed no attack. On the contrary, in QP1 only 9.3% were ivy-free, while 45.7% were concerned by *strong* attack (table 2). No specific investigation was carried out as regards the causes of differences in attack intensity between the two situations. Anyway, according to Thomas (1998), it is likely that variability in microtopographical conditions could have an important role in influencing ivy spreading. In particular, as reported by Beekman (1984), English ivy suffers root asphyxia, so it does not tolerate too heavy soils.

It must be pointed out that in QP1, higher dbh values were found in oaks according to the raising intensity of the vine attack (table 2). Similarly, in the hardwood alluvial Rhine forest, the biggest and vigorous trees hosted the most luxuriant ivy (Trémolières et al. 1988).

TABLE 1. Main biometric features of the investigated stands and of the sampled sets of trees. All values are means ± 1 standard deviation

		non-host trees	host trees	ivy
investigated stands	*diameter (cm)*	14.3 ± 5.7	12.3 ± 4.4	–
	height (m)	10.7 ± 2.0	9.4 ± 2.4	–
sampled trees	*diameter (cm)*	18.2 ± 3.4	18.3 ± 2.6	5.9 ± 2.4
	height (m)	10.8 ± 0.7	10.5 ± 0.7	9.2 ± 0.7
	trunk biomass (kg)	160.1 ± 52.9	147.1 ± 45.2	58.9 ± 15.5
	branches biomass (kg)	33.9 ± 13.2	24.6 ± 15.5	56.6 ± 23.3

TABLE 2. Frequency of trees and the respective diameter variation according to the intensity of ivy attack in the investigated stands. Values of diameter are means ± 1 standard deviation

	host stand		non-host stand	
	frequency (%)	*diameter (cm)*	*frequency (%)*	*diameter (cm)*
no-attack	9.3	9.6 ± 4.1	81.6	11.7 ± 4.2
weak	24.7	10.9 ± 4.2	17.6	14.8 ± 4.1
moderate	20.4	13.6 ± 4.1	0.8	14.4 ± 6.6
strong	45.7	17.4 ± 5.6	0.0	–

Despite these results, the mean and the individual epigeal biomass (table 1, figure 1*a-b*) of host trees is usually lower in respect of non-host trees. Nevertheless, a clear idea of the invading ability of the vine is quite well got from the values of its branches biomass, which can even exceed 7 times the one of the respective hosting tree (figure 1*b*).

As showed in tree ring chronologies (figure 2*a*), ivy was established about 1955, that is a dozen years after the coppicing event which issued the sampled populations of trees. This is consistent with the assumption that the climbing behaviour of ivy is possible only when a solid and continuous support is available (Beekman 1984).

Fluctuations in radial and height growth of both oak populations can be highlighted (figure 2*a-b*). Some evidences in curves of radial growth suggest a probable influence of ivy. Firstly, the two tree ring curves of host and non-host populations are quite well synchronised, whereas differences are observed between oak and vine. This aspect most probably reflects diversity in the ecology of the two species. Secondly, three peculiar phases - *A*, *B* and *C* - characterise the curves (figure 2*a*). In *phase A*, the suppression and the following release in both oak populations is to be probably related to coppicing events, that occurred in 1965 and 1968, respectively in host stand and in non-host stand. Such an assumption is also suggested by the reduction in height growth rate observed in the period before coppicing in both oak populations, but not in the vine (figure 2*b*). In this time span, ivy grew intensively and seemed to affect positively the growth of the hosting trees, that showed a global higher growth rate than non-host trees. In *phase B*, the growth rate of the two oak populations is quite similar. In *phase C* the growth rate of the host population became lower than that of the non-host population, so the ivy influence appears to become negative. The former suggestion is consistent with the general idea that vines have deleterious effects on forest tree species by direct physical suppression, shading or root competition, as in the case of the exotic *Lonicera japonica* vs. *Liquidambar styraciflua* in the Maryland, U.S.A. (Whigham 1984). Nevertheless, examples of positive interaction are also known for several species from the Rhine Valley, France (Trémolières et al. 1988), and beech from the Gargano, South Italy (Nola 1997). Such kinds of responses could be likely explained by the important role of ivy litter in nutrients turn-over (Trémolières et al. 1988). In fact, it decomposes rapidly in spring, during the most active growth phase of the other forest tree species, so supplying nutrients and stimulating the microflora activity.

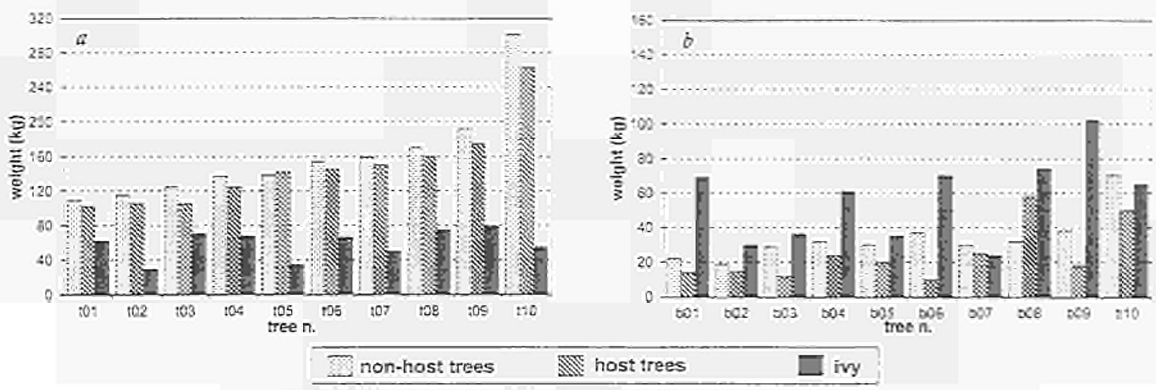

FIGURE 1. Biomass of trunk (*a*) and branches (*b*) of the ten sampled trees

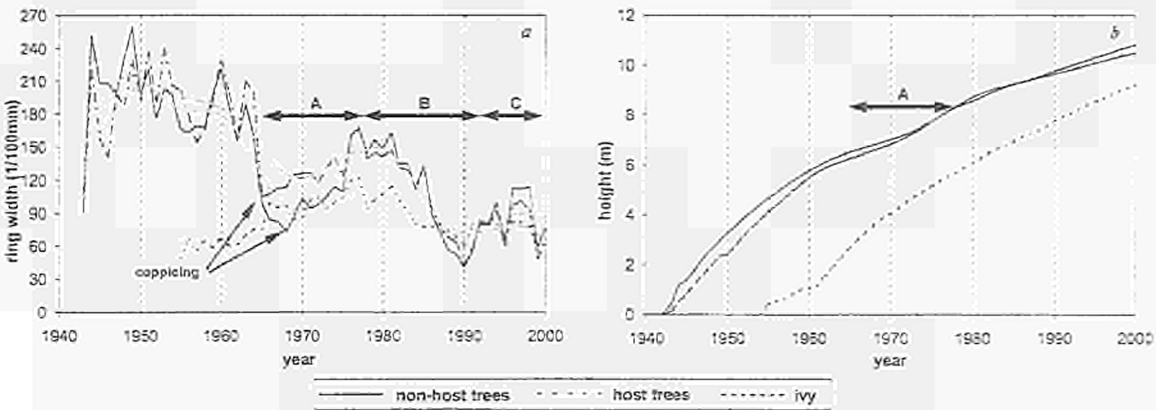

FIGURE 2. Master tree ring chronologies (*a*) and height variation through time (*b*) of the investigated populations

In conclusion, it can be assumed that, after a cooperative phase, the further development of the vine involves the onset of light (and perhaps root) competition to the detriment of host trees, that in the most severe cases can even die. According to these results, changes in the traditional use of resources have given rise to new problems that must be taken into account in the future management of the protected areas. A continuous monitoring of forest evolution is needed in order to assess the proper intervention aiming at maintaining or improving the ecosystem stability.

References

Beekman, F. 1984. La dynamique d'une forêt alluviale rhénane et le rôle des lianes. *In* Les forêts alluviales, pp. 475-501. Colloques phytosociologiques, IX, Strasbourg, 1980.

Kolishchuk, V. G. 1990. Dendroclimatological study of prostrate woody plants. *In* Methods of dendrochronology - Application to the environmental sciences, pp. 51-55. Edited by E. R. Cook and L. A. Kariutskis. Kluwer Ac. Publ., Dordrecht.

Nola, P. 1997. Interactions between *Fagus sylvatica* L. and *Hedera helix* L.: a dendrochronological approach. Dendrochronologia, 15 : 23-37.

Rondeux, J. 1993. La mesure des arbres et des peuplements forestièrs. Les Presses Agronomiques de Gembloux, Gembloux, 521 p.

Thomas Jr., L. K. 1998. Topographic alterations, forest structure and invasion by English ivy (*Hedera helix* L.) in the rock Creek Floodplain, Washington, D.C.. Natural Areas Journal, 18: 164-168.

Trémolières, M., Carbiener, R., Exinger, A. M. and Turlot, J. C. 1988. Un exemple d'interaction non compétitive entre espèces ligneuses : le cas du lierre arborescent (*Hedera helix* L.) dans la forêt alluviale. Acta Oecol./Oecol. Plant., 9 (2): 187-209.

Whigham, D. 1984. The influence of vines on the growth of *Liquidambar styraciflua* L. (sweetgum). Can. J. For. Res. 14: 37-39.

Analysis of land use in Sicilian *NATURA 2000* sites and in Protected Areas for an ecological network implementation

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Abstract
The recent European environmental policy aims at promoting the creation of a European Ecological Network. According to that, in the present paper we carried out an analysis about the distribution and the general features of the whole Sicilian system of Protected Areas and other areas of high naturalistic value (pCIS and SCZ). Results showed that Protected Areas and pCIS/SCZ globally cover nearly 13% of the total regional surface, but they are not uniformly distributed in the territory of the region. Moreover, many Reserves and pCIS/SCZ are isolated and scattered. Natural vegetation share is higher in Parks (about 84% of the total area), as respect to Reserves and pCIS/SCZ (63.6% to 75.5%). Although satisfactory in the quantitative point of view, the creation of a regional ecological network requires forthright actions in order to implement and/or improve the connectivity among Parks, Reserves and the whole grid of external to Protected Areas pCIS/SCZ.

Keywords: Corine Land Cover, Land use, NATURA 2000, pCIS, Protected Areas, SCZ

1. Introduction

In the last years, the need to create ecological information systems at wide scale emerged in many European countries in order to enhance the management and the conservation of the natural resources. This goal promoted different kinds of studies in the field of landscape ecology in several European countries, in the aims of inventorying and describing the environmental resources in a georeferenced system. An example is the study carried out at the beginning of the nineties in order to create a programme document to realise an "*European Ecological Network*" in the European Community (EECONET) (Benett, 1991 e 1994). The main points of this project were the identification and the conservation of particular units of the landscape such as: *i*) characteristics core areas, *ii*) biocorridors.
Recent attention on the conservation of biodiversity influenced the EU policy and conspicuous financial supports have been given to encourage the protection of particular indigenous forests, as well as afforestation actions in agronomic fields, as reported in Agenda 2000 (Environmental Policy in the Southern Member States, 1998). These actions were also accepted by the Italian Government in the Piano Nazionale sulla Biodiversità (Ministero Ambiente, 1997), which considers knowledge and monitoring as the basic tools to protect the most important natural areas.
The basic elements for the conservation of biological diversity in EU are the Special Conservation Zones (SCZ) (Directive "Bird" 79/409/EEC, adopted in Italy by the Law 157/92) and the proposed Community Importance Sites (pCIS) (Directive "Habitat" 92/43/EEC, adopted in Italy by the Rule 357/97). Both directives identify all naturalistic areas of interest in the point of view of conservation of birds, habitats and other species of community importance. Their application provides a concrete contribution to the implementation in Europe of international conventions on conservation of biodiversity, such as the Convention of Berne (82/72/EEC) and the Convention on Biodiversity (93/626/EEC).
Since two decades, the Region Sicily has been promoting a protection policy for naturalistic value areas. According to that, in 1981 a program was initiated aiming at the creation of a regional system of protected areas, which at present is composed by 3 Regional Parks (total area 183835 ha) and 76 Nature Reserves (85676 ha) (Regional Laws 98/81, 14/88, 970/91).
In the present paper, the distribution and the general features of the whole Sicilian system of protected areas and other areas of high naturalistic value (*pCIS* and *SCZ*) are described.

2. Methods

The basic data were represented by the land use classification of Sicily according to CORINE Land Cover level 1 and 3. The corresponding maps were overlaid to the cartographic data of Protected Areas and pCIS/SCZ; the formers were obtained from the Bioitaly Programme, that is the Italian contribution to the creation of the European NATURA 2000 Network (Directive "Habitat" 92/43/EEC). The analysis was performed by the GIS ArcView 3.2.

3. Results and discussion

The total amount of the current protected areas (269520.98 ha) and pCIS/SCZ (370342.73 ha) is relevant (about 18%) as related to the total surface of Sicily (2582588.48 ha) (table 1). However, their distribution is not homogeneous in the regional territory (figure 1). The three Regional Parks and most of the Nature Reserves are concentrated in the Northern mountainous ranges, whereas pCIS/SCZ are scattered in the rest of the territory (figure 1). Moreover, it must be pointed out that many pCIS/SCZ are internal to the protected areas, so the total surface of these sites actually valuable for the ecological network is much lower (194313.21 ha).

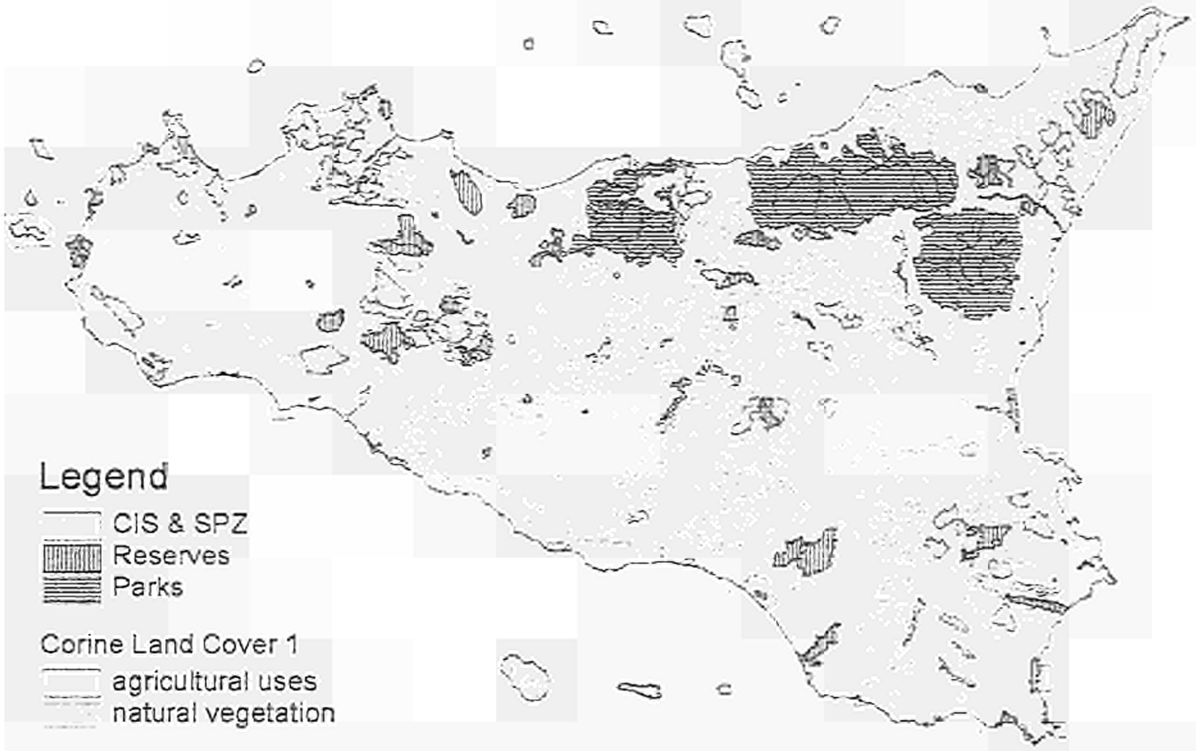

Figure 1 - Land use of Sicily according to CORINE LC1 classification and distribution of NATURA 2000 sites (pCIS/SCZ), Parks and Reserves

As regards the land use categories (level CORINE LC1), the Nature Parks surface is mainly covered by "natural vegetation" (83.78% of the total Park's area), whereas only 15.85% is represented by "agricultural lands". The situation is a bit different in reserves and external pCIS/SCZ, as we observe a lower rate for "natural vegetation" and a higher one for "agricultural lands". Especially in reserves, the agricultural activities still maintain a notable economic importance. But the high share of the concerned surface is to be related to the fact that the object of conservation is often a punctiform emergence, whose protection requires a large buffer zone. Typical examples are the volcanic phenomena of Maccalube di Aragona Reserve, or the Grotta di Santa Ninfa Reserve (La Mantia and Pasta, 2001; Pasta and La Mantia, 2001). In addition, some agricultural activities have a main role in preserving the necessary life conditions for a number of animals, as shrikes (*Lanius* spp.), whose habitats are represented by sowable lands with sparse trees (La Mantia, 1997b).

In respect of the surface of each category, the Parks include almost 50% of the total "natural vegetation" area, but a considerable share is contained in not yet protected areas (pCIS/SCZ).

The reserves, due to their scattered distribution, have a major role in safeguarding some peculiar habitats, such as wetlands and waterbodies, respectively represented by 3.16% and 0.45% of the protected area, and by 89.18% and 12.13% if referred to the total of the two respective categories of land use (table 1a). At this regard, it must be pointed out that especially the waterbodies should notably increase (up to about

96%, *i.e.* more than 3000 ha) if the corresponding surfaces included in external pCIS/SCZ are taken into account (table 1b). Actually, the external pCIS and SCZ should allow the preservation of areas that have a strategic importance for migratory birds, especially ducks and waders, that are the usual visitors of such habitats, unlike passerines and predators, normally concentrated in stop-over and wintering areas.

It must be also noticed that the land use categories "natural vegetation", "wetlands" and "waterbodies" in actual and potential protected areas cover more than 13% of the total region area.

a

CATEGORY	*Nature Parks*			*Nature Reserves*			*external pCIS*			*external SCZ*		
	(ha)	(%)*	(%)**	(ha)	(%)*	(%)**	(ha)	(%)*	(%)**	(ha)	(%)*	(%)**
natural vegetation	154023.44	83.78	46.14	54467.55	63.57	16.32	86634.23	63.68	25.95	38700.77	75.46	11.59
agricultural uses	29142.42	15.85	24.48	26727.69	31.20	22.45	45799.41	33.66	38.48	17365.10	20.23	14.59
wetlands	0.00	0.00	0.00	2704.26	3.16	89.18	49.49	0.04	1.63	278.46	1.98	9.18
waterbodies	113.14	0.06	3.54	387.83	0.45	12.13	1590.26	1.17	49.74	1106.09	1.22	34.59
artificial surfaces	565.94	0.31	11.93	1388.70	1.62	29.27	1973.13	1.45	41.59	816.28	1.11	17.21
TOTAL	183844.94	100.00	--	85676.03	100.00	–	136046.52	100.00	--	58266.70	100.00	–

b

CATEGORY	*total pCIS* (external + internal)			*total SCZ* (external + internal)			*Total PA and external pCIS/SCZ*		*Total PA and external pCIS/SCZ / Total surface of Sicily*	*Total of categories in* Sicily
	(ha)	(%)*	(%)**	(ha)	(%)*	(%)**	(ha)	(%)	(%)	(ha)
natural vegetation	180064.03	66.42	53.94	92590.53	72.71	27.74	333825.99	71.97	12.93	674510.832
agricultural uses	63416.14	29.80	53.28	24824.99	25.61	20.86	119034.62	25.66	4.61	1785583.406
wetlands	154.21	0.48	5.09	2433.43	0.06	80.25	3032.21	0.65	0.12	2791.455
waterbodies	1640.11	1.90	51.30	1496.12	0.67	46.79	3197.32	0.69	0.12	6765.503
artificial surfaces	2362.11	1.40	49.79	1361.05	0.95	28.69	4744.05	1.02	0.18	112937.289
TOTAL	247636.60	100.00	–	122706.12	100.00	–	463834.19	100.00	17.96	2582588.486

*referred to the type of area
** referred to the category of land use

Table 1 – Land use in Sicilian Parks, Reserves and pCIS/SCZ according to CORINE LC1 classification

More detailed information about land use is provided by CORINE LC3 classification. Within the "natural vegetation", the type "deciduous forest" is well represented in Protected Areas (figures 2a, b), but not in pCIS/SCZ (figures 2c, d), whereas "coniferous forest" and "mixed forest" always show a much lower share. Such a situation reflects the recent policy to preserve the last remnants of indigenous forests in Sicily. We highlight that almost the whole of these forests are presently constituted by aging coppices no longer exploited since at least four decades; they are currently very simplified in structure and floristic composition. Their significance in the naturalistic and in the biodiversity point of view is nevertheless high, as they represent the last evidence of the ancient vegetal landscape in Sicily. Changes in traditional land use are probably responsible of the high amount of the type "vegetation in evolution", that can be noticed in all kinds of sites and particularly in parks. In most cases this *type* is to be referred to vegetation dynamic processes that are taking place in marginal agricultural lands, following the massive abandonment of cultivated lands.
"Sclerophyllous vegetation" rate is quite low in parks (4.4%), whereas it is two to three and half times higher in the other kinds of sites. This is likely due to the prevailing localisation of parks in mountainous areas, where other types of vegetal communities are usually more common. In the point of view of floristic biodiversity, a major role is to be attributed to the "natural pasturelands", that show the highest frequency in non-protected areas. The dominant vegetal communities are Mediterranean grasslands, sometimes with scattered trees and shrubs, attributable to the class *Thero-Brachypodietaea*. They often result from the centennial disturbance of human actions.
Some particular remarks can be done for "agroforestry areas", although they are only found in external pCIS with a share of just 0.43%. This type refers to all systems that: *i*) usually bases on two (or more) tree species, within which one at least is a permanent woody species, *ii*) always have two or more different kinds of outputs, *iii*) have a production cycle always longer than one year (Nair, 1993). In Sicily, a large amount of surface is concerned with this type (e.g. manna ash, carob or hazel groves), which is especially localised in Madonie and Nebrodi Parks and in the South-Eastern part of the region (Cullotta *et al.*, 1998). Its quite scarce presence in our analysis could be explained by an

incorrect classification in CORINE LC3; actually, this type could have been included within as "complex agricultural systems" or "orchards". Considering the great importance of agroforestry systems in the point of view of their landscape and cultural value, a more accurate land use analysis is highly desirable in the forthcoming preparation of CORINE LC4 classification.

4. Conclusion

The results of our analysis point out, firstly, that the current system of Protected Areas in Sicily has a not uniform distribution in the whole territory of the region. Although most of the indigenous forest stands are concentrated in the Northern sector, many other types of natural vegetation, as steppic or garigue communities, have an extremely important value in the context of biological diversity and conservation of several species of flora and fauna (cfr. AA.VV., 2001). Moreover, the establishment of small or punctiform protected areas, though necessary to preserve some peculiar habitats, does not make possible the genic flow between isolated populations of organisms, as they are most often isolated.

In order to realise an efficient ecological network, much must be still done in terms of increasing the density of core areas and improvement of the naturalness in the existing ones. In Sicily, several investigations (La Mantia 1997a; Massa and La Mantia, 1997) have confirmed the importance of biocorridors in maintaining biodiversity. Hence, forthright actions must be carried out in order to implement the connectivity between the already Protected Areas and the whole grid of external pCIS/SCZ. For example, interventions of naturalistic restoration in many degraded watercourses and the creation of biocorridors, where necessary, can contribute to the realisation of a connective eco-structure. Some proposals of intervention have been recently promoted (Corona *et al.*, in press), but many obstacles, *e.g.* wildfires, make the task very difficult.

In conclusion, the effective conservation of the Sicilian natural inheritance can be secured by promoting different initiatives, such as: *i)* undertaking a proper and concrete management in Protected Areas and assessing the management guidelines in pCIS/SCZ, both up to present lacking, *ii)* implementing interventions to improve the connectivity among all the naturalistic areas of the region in order to create a functional ecological network.

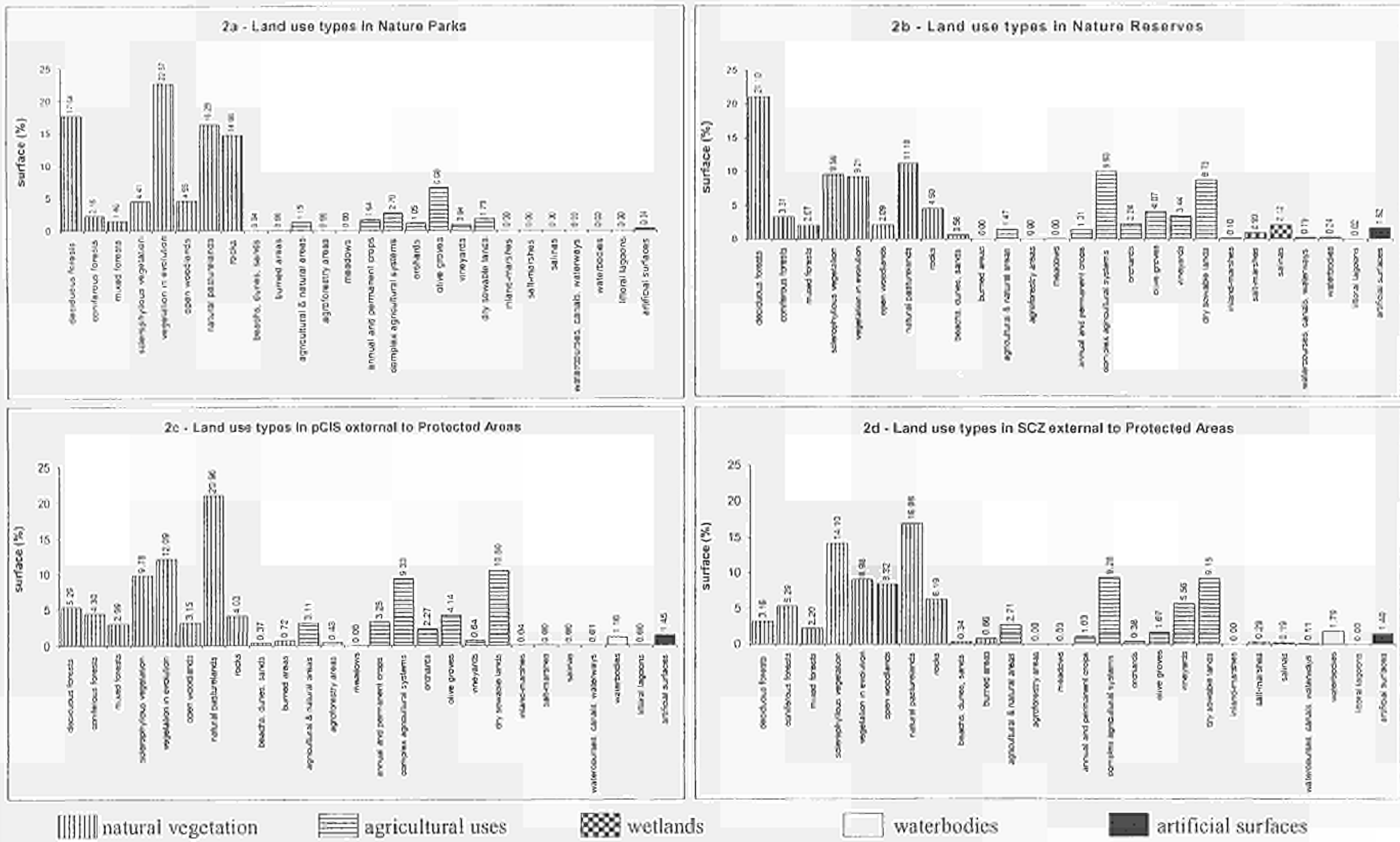

Figure 2 - Land use in Sicilian Parks, Reserves and external pCIS/SCZ according to CORINE LC3 classification

References

A.A. V.V. (G. Casamento, ed.), 2001 - Le riserve naturali siciliane gestite da Legambiente: un contributo alla conoscenza e alla tutela. Naturalista Siciliano, S. IV, XXV (Suppl.): 464.

Benett G. (ed.), 1991 – *Towards a European Ecological Network*. Institute for European Environmental Policy, Arnhem, 80 pp..

Benett G. (ed.), 1994 – *Conserving Europe's natural heritage. Towards a European ecological Network*. Proceedings of the international conference held in Maastricht, 9-12 November 1993. Graham and Trotman/Martinus Nijhof, London, Dordrecht Boston, 334 pp..

Corona P., Chirici G., Barbera G., Cullotta S., La Mantia T., La Mela Veca D.S., Marchetti M., Messana G., In press - Confronto e misurazione dell'organizzazione spaziale di paesaggi collinari mediterranei. Atti del Seminario "Biodiversità nei paesaggi agrari forestali", Palermo-Pantelleria 31 maggio-2 giugno. Quaderni I.A.E.D..

Cullotta S., La Mantia T., Barbera G., 1998 - Descrizione e ruolo dei sistemi agroforestali in Sicilia. Atti "*Secondo Congresso Nazionale di Selvicoltura per il miglioramento e la conservazione dei bochi italiani*" Venezia dal 24-27 giugno, 1998, Vol. IV: 429-440.

Environmental Policy in the southern member states, 1998 – Discussion document draft 2, EEA, Copenhagen.

La Mantia T. 1997a - Il ruolo degli elementi diversificatori negli agroecosistemi mediterranei: valorizzazione e relazioni con le popolazioni di vertebrati. *Naturalista sicil.*, Vol XII (suppl.): 175-211.

La Mantia T. 1997b - Agricoltura, pastorizia e forestazione: impatto e ruolo nella conservazione. Lavoro presentato al *XIII° workshop "La conservazione della fauna terrestre in Sicilia: azione, educazione, strategia"*, Scuola Internazionale di Etologia, Erice, 7-9 novembre 1997.

La Mantia T., Pasta S. 2001 - La rinaturalizzazione dei rimboschimenti: proposte metodologiche e ipotesi di intervento nella Riserva Naturale "Grotta di Santa Ninfa". Naturalista Siciliano, S. IV, XXV (Suppl.): 299-323.

Massa B., La Mantia T. 1997 - Benefits of hedgerows-windbreaks for birds and their valorisation in sustainable agriculture. *Agricoltura Mediterranea*, 127: 332-341.

Ministero Ambiente, 1997 - *Piano Nazionale sulla biodiversità*. All. Ambiente Informa 9, 1999.

Nair P.K.R. 1993 - *An Introdution to Agroforestry*. Kluwer Academic Publishers, The Netherlands.

Pasta S., La Mantia T. 2001 - L'impatto dell'attività agricola e la gestione delle aree protette: il caso della Riserva Naturale "Maccalube di Aragona. *Naturalista Siciliano*, S. IV, XXV (Suppl.): 197-215.

Synphytosociological and ecological analysis of landscape applied to the management of protected areas in Sicily. 1 "Isola di Pantelleria" Natural Reserve

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Abstract

The results of a study on the landscape of the "Isola di Pantelleria" Natural Reserve are here presented. On the ground of releves carried out in uniform areas according to modern synphytosociological criteria, from bioclimatical and edaphic point of view, the different phytocoenoses were analyzed. Besides the methodology adopted for realization of actual (scale 1:10000) and potential vegetation maps (scale 1:50000), is here discussed. The two elaborates represent good scientific instruments for a territorial planning and management.

Keywords: Sicily Channel, "Isola di Pantelleria" Natural Reserve, synphytosociology, phytoecological cartography

1. Introduction

The plant communities are expressions of the interaction among edaphically, bioclimatically, anthropically and chorologically factors, and represent remarkable indicators for understanding the landscape. In the last few years the studies on syndinamism of vegetation have been developed on the base of the modern methodology related to the Synphytosociology and Geosynphyitosociology (Gehù and Rivas-Martinez 1981; Biondi 1994). This study deals with the concept of "vegetation series" (or sigmetum), defined by Rivas-Martinez (1997) "geobotanical unit expressing all the various stages of plant communities that can be found in similar teselar palces as a result of the succession process, including together with the representative vegetation type of mature stage of the series head (climax) the initial or subseral communities replacing them.".

According to this methodology, the cartographic elaborate and the study on natural vegetation can be employed as scientific instruments for territorial planning and management.

The results of a study on the landscape of the "Isola di Pantelleria" Natural Reserve are here presented.

2. Results and discussion

The Island of Pantelleria represents the emerged part of a huge volcanic edifice sited in Sicily Channel, along a drowned continental rift, between Sicily and Tunisia (Figure 1). The geographical position, the geomorphology of its territory, the zoological, floristic and phytocoenotic characteristics, as well as the human historic action, make Pantelleria one of the most interesting islands of Mediterranean basin.

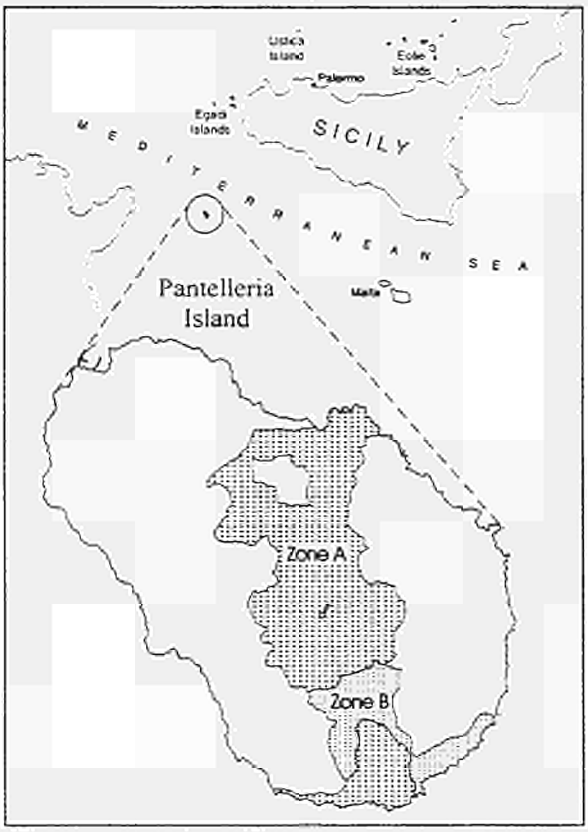

FIGURE 1 - Index Map of "Isola di Pantelleria" Natural Reserve.

TABLE 1 - Scheme of vegetation series of "Isola di Pantelleria" Natural Reserve.

Inframediterranean semiarid belt

VEGETATION OF COASTAL CLIFFS

- *Limonium cosyrense* (Guss.) O. Kuntze community (*Limonietum cosyrensis* Brullo, Di Martino et Marcenò 1977)
- *Helichrysum rupestre* (Rafin.) DC. var. *errerae* (Tin.) Pignatti community (*Matthiolo pulchellae-Helichrysetum errerae* Brullo, Di Martino et Marcenò 1977)
- Subhalophilous therophytes grassland (*Sileno sedoidis-Bellietum minuti* Brullo 1985)

VEGETATION OF SUBCOASTAL ROCKY SUBSTRATA

- *Juniperus turbinata* Guss. maquis (*Periploco angustifoliae-Juniperetum turbinatae* Brullo, Di Martino et Marcenò 1977 subass. *brassicetosum insularis* Gianguzzi 1999)
- *Periploca angustifolia* Labill. low maquis (*Periploco angustifoliae-Euphorbietum dendroidis* Brullo, Di Martino et Marcenò 1977 subass. *typicum*)
- *Coridothymus capitatus* Rchb. f. garrigue (*Rosmarino-Coridothymetum capitati* Furnari 1965 subass. *lavanduletosum stoechadis* Brullo, Di Martino et Marcenò 1977)
- *Hyparrhenia hirta* (L.) Stapf. steppe (*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl.1950)
- Ephemeral grassland (*Crassulo tilleae-Sedetum cosyrensis* Brullo, Di Martino et Marcenò 1977)

Thermomediterranean dry belt

VEGETATION OF LITHOSOLS

- *Quercus ilex* L. bushland (*Erico arboreae-Quercetum ilicis* Brullo, Di Martino et Marcenò 1977 subass. *typicum* and subass. *juniperetosum turbinatae*)
- *Calicotome villosa* (Poiret) Link and *Cistus* sp. pl. garrigue (*Cisto-Ericion* Horvatic 1958)
- *Hyparrhenia hirta* (L.) Stapf. steppe (*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl.1950)
- Ephemeral grassland (*Crassulo tilleae-Sedetum cosyrensis* Brullo, Di Martino et Marcenò 1977)

VEGETATION OF LITHOSOLS-REGOSOLS

- *Pinus halepensis* Miller pine-wood (*Pistacio lentisci-Pinetum halepensis* De Marco et Caneva 1985)
- *Rosmarinus officinalis* L. and *Erica multiflora* L. garrigue (*Genisto-Rosmarinetum officinalis* Gianguzzi 1999 subass. *typicum*)
- *Hyparrhenia hirta* (L.) Stapf. steppe (*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl. 1950)
- Ephemeral grassland (*Crassulo tilleae-Sedetum cosyrensis* Brullo, Di Martino et Marcenò 1977)

VEGETATION OF REGOSOLS-ANDOSOLS

- *Pinus pinaster* Aiton subsp. *hamiltonii* (Ten.) Huguet del Villar pine-wood (*Genisto aspalathoidis-Pinetum hamiltonii* Brullo, Di Martino et Marcenò 1977 subass. *typicum*)
- *Genista aspalathoides* Lam. Broom field (*Genisto aspalathoidis-Rosmarinetum officinalis* Gianguzzi 1999 var. *Arbutus unedo*)
- *Ampelodesmos mauritanicus* (Poiret) Dur. et Sch. steppe (*Ampelodesmos mauritanicus* aggr.)
- Ephemeral grassland (*Trifolio dolychodon-Andryaletum cosyrensis* Brullo, Di Martino et Marcenò 1977)

Mesomediterranean subhumid belt

VEGETATION OF LITHOSOLS

- *Quercus ilex* L. woodland (*Myrtus communis* facies of *Erico arboreae-Quercetum ilicis* Brullo, Di Martino et Marcenò 1977)
- *Cistus* L. sp. pl. garrigue (*Cisto-Ericion* Horvatic 1958)
- *Brachypodium rupestre* (Host) R. et S. steppe (*Brachypodium rupestre* aggr.)
- Ephemeral grassland (*Trifolio dolychodon-Andryaletum cosyrensis* Brullo, Di Martino et Marcenò 1977)

VEGETATION OF REGOSOLS-ANDOSOLS

- *Pinus pinaster* Aiton subsp. *hamiltonii* (Ten.) Huguet del Villar pine wood (*Genisto aspalathoidis-Pinetum hamiltonii* Brullo, Di Martino et Marcenò 1977 subass. *arbutetosum unedonis* Gianguzzi 1999)
- *Arbutus unedo* L. and *Erica arborea* L. brush (*Erico arboreae-Arbutetum unedonis* Allier et Lacoste 1980 subass. *cistetosum salvifolii*)
- *Pteridium aquilinum* (L.) Kuhn. community (*Pteridium aquilinum* aggr.)
- Ephemeral grassland (*Trifolio dolychodon-Andryaletum cosyrensis* Brullo, Di Martino et Marcenò 1977)

Edaphophilous geoseries

VEGETATION OF SPECCHIO DI VENERE LAKE

- *Limonium secundirameum* (Lojac.) Brullo community (*Limonietum secundiramei* Brullo, Di Martino et Marcenò 1977)
- Helophytic community (*Cypero laevigati-Schoenoplectetum thermalis* Brullo, Di Martino et Marcenò 1977)
- Algal communities (Fitoplancton)

VEGETATION OF FUMAROLAS

- Cyanophyceae communities
- Cryptogamic communities
- *Radiola linoides* Roth. and *Kickxia cirrhosa* (L.) Fritsch community (*Radiolo linoidis-Kickxietum cirrhosae* Brullo, Di Martino et Marcenò 1977)

VEGETATION OF PONDS

- *Isoetes durieui* Bory community (*Isoeto durieui-Ranunculetum parviflori* Brullo, Di Martino et Marcenò 1977)

"Isola di Pantelleria" Natural Reserve was established by "D. A. n. 741/44 del 10.12.1998 (G.U.R.S. n. 24, del 21.05.1999)", and managed by Azienda Foreste Demaniali della Regione Siciliana. It is 2626,69 ha wide: 2145,37 ha in zone A and 481,32 ha in zone B.
From a naturalistic point of view, the protected area covers the most valuable part of the island, including: the south-eastern coastal belt, the higher peaks as Cuddia Attalora (560 m s.l.m.), Monte Gibele (700 m s.l.m.) and Montagna Grande (836 m s.l.m.), the lava flows of Gelfizer, Cuddia Randazzo and Khaggiar; and the remarkable aquatic biotope of "Specchio di Venere" lake (Calvo and Gianguzzi 2001).

Based on a bibliographic data and on inedited field researches, a phytocoenotic cartographic representation was elaborated.

Several phytosociological releves based on Braun-Blanquet (1964) method, allowed to recognize the plant communities and associations characterizing the units of Dynamic Phytosociology described (as ecologically homogeneous territory). Special attention was paid to forest formations as most mature stages of vegetation series (*Quercus ilex*, *Pinus halepensis* and/or *Pinus Pinaster* ssp. *hamiltonii* woods); and the physiognomically subseral communities widespread (scrubs, garrigues, grasslands, etc.).

The scheme of vegetation series is showed in Table 1 and reports the plant communities characterizing climatophilous series and geoseries (edaphophilous series) set according to edaphic and bioclimatical criteria.

The most mature stages of progressive successions are represented by *Juniperus turbinata* and *Periploca angustifolia* maquis (inframediterranean belt), *Quercus ilex* wood (thermomediterranean and mesomediterranean belts) that colonize the recent lava flows and outcrops (*Rock outcrop-Lithic Xerorthents*). On Regosols (*Typic Xerorthents*) and Andosols (*Andic Xerorept*), most occupied by cultivations, there are vegetation series of *Pinus halepensis* (lower thermomediterranean belt) and of *Pinus pinaster* subsp. *hamiltonii* (mesomediterranean belt). In the innermost bioclimatical belt, mixed pine-wood aspects are present (upper thermomediterranean belt). In the island *Pinus pinaster* subsp. *hamiltonii* reaches the south-eastern limit of its distribution range (Greuter, Burdet and Long, 1984), with a forestal population extended on a 800 ha surface.

Apart from the map of actual vegetation of Pantelleria island reserve (scale 1:10000), the map of vegetation series (scale 1:50000) (describing equipotential territorial units according to ecologically homogeneous factors) was elaborated. Besides, phytocoenotic data can be applied to preserve natural aspects and restore the scattered vegetation (i.a. burnt area sited in Contrada Dietro Isola, along southern slopes of Cuddia Attalora).
The two maps can be employed as scientific planning instruments for management programs of naturalistic type.

Notes
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References

Biondi, E. 1994. The phytosociological approach to landscape study. Annali di Botanica 52: 135-141.
Braun-Blanquet, J. 1964. Pflanzensoziologie. Springer: Wien-New York.
Brullo, S., Di Martino, A. and Marcenò, C. 1977. La vegetazione di Pantelleria (Studio fitosociologico). pp. 1-111. Pubbl. Ist. Bot. Univ. Catania.
Calvo, S. and Gianguzzi, L. 2000. Aspetti naturalistici ed ecologici del Lago Specchio di Venere nell'Isola di Pantelleria. GEAM (Geoengineering Environment and Mining) 37 (1): 25-32.
Di Martino, A. 1963. Flora e vegetazione dell'Isola di Pantelleria. Lav. Ist. Bot. Giard. Col. Palermo 19: 1-159.
Gianguzzi, L. 1995. A vegetation map (1: 20.000) of Pantelleria island. Giorn. Bot. Ital. 129 (2): 249.
Gianguzzi, L. 1998. Indagini per una cartografia della vegetazione dell'Isola di Pantelleria. Arch. Geobot. 4(1): 109-114.
Gianguzzi, L. 1999a. Vegetazione e bioclimatologia dell'Isola di Pantelleria. Braun-Blanquetia 24: 1-70.
Gianguzzi, L. 1999b. Il paesaggio vegetale dell'Isola di Pantelleria. In Collana Sicilia Foreste 6, pp. 1-192. Edited by Azienda Foreste Demaniali della Regione Siciliana: Palermo.
Géhù, J.-M. and Rivas-Martinez, S. 1981. Notion fondamentales de Phytosociologie. Ber. Int. Simp. Int. Veingung Vegetationsk: 5-33.
Greuter, W., Burdet, H.M. and Long, G. 1984-1989. Med-Checklist 1-3-4. Genève.
Rivas-Martinez, S. 1987. Notiones sobre Fitosociologia, Biogeografia y Bioclimatologia. In La vegetacion de Espana, pp. 19-45. Edited by Universidad de Alcalà de Henarez.
Villari, L. 1974. The island of Pantelleria. Bull. Vulcano l. 38: 680-724.

Synphytosociological and ecological analysis of landscape applied to the management of protected areas in Sicily. 2. "Monte Cofano" Natural Reserve

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Abstract
The preliminary results of a synphytosociological study of the "Monte Cofano" Natural Reserve (Sicily NW), carried out as a basis for the future publication of map of vegetation (1:20000), are here presented. Besides the syntaxonomical typification of the studied coenoses, the different series and geoseries have been characterized. The correlation between the thermopluviometric data and the vegetation features showed a remarkable bioclimatical diversification of the territory, with two different belts, i.e. thermomediterranean upper dry and mesomediterranean lower suhumid. This study could provide a basic ground for the management of the protected area.

Keywords: Sicily, "Monte Cofano" Natural Reserve, synphytosociology, phytoecological cartography

1. Introduction

The landscape alteration along the coastal belt represents a remarkable problem within the Mediterranean basin; here the hard exploitation of environmental resources caused a considerable reduction of natural and subnatural habitats. "Monte Cofano" (695 mts.), located in north-western Sicily, still represents one of the most notable areas of the island because of its biogenetic and ecological value. This site is an important refugium for some very threatened elements of the coastal fauna; besides, the rocky slopes of the mountain show remakable vegetation aspects characterized by several endemic species and other taxa of phytogeographic interest (Raimondo et al. 1992). Some of these ones are local, as *Erica sicula* Guss., *Helichrysum rupestre* (Rafin.) DC. var. *cophanense* Brullo, *Phagnalon metlesicsii* Pign. and *Hieracium cophanense* Lojac.; the last one is present in Zingaro Natural Reserve too (Raimondo et al. 1986).

The preliminary results of a synphytosociological study of the "Monte Cofano" Natural Reserve, carried out as a basis for the future publication of map of vegetation (1:20000), are presented in this study.

2. Results and discussion

The Natural Reserve of "Monte Cofano" occurs at the Custonaci territory (Trapani district) along the coastal and subcoastal belt, from Cala Buguto towards S. Vito Lo Capo, up to Case Poma and Polisano. Protected area is 537,5 ha wide: 352,5 ha in zone A and 185 ha in zone B (Figure 1). The studied area is included in "foglio" n. 593 "Castellammare del Golfo" (I.G.M.I. 1:50.000), in "tavoletta" n. 248 III N.E. "Monte Cofano" (I.G.M.I. 1:25.000) and in sections n. 592080, 592120, 593050 and 593090 (C.T.R. 1:10.000) of "Carta Tecnica Regionale".

Mt. Cofano massif (659 m s.l.m.) is sited in zone A and represents an important biotope for its scientific and natural values (Mazzola et al. 1984 Raimondo et al. 1990). The importance of this area was just highlighted by Pignatti (1979) who included it in most important Italian sites interested in conservation list of natural vegetation. Besides in Mt. Cofano reserve there are archeological sites and historical buildings as Spanish towers and a "tonnara".

"Monte Cofano" Natural Reserve is included in the "Piano Regionale dei Parchi e delle Riserve Naturali (L.R. 98/81 and 14/98)"; it was established by

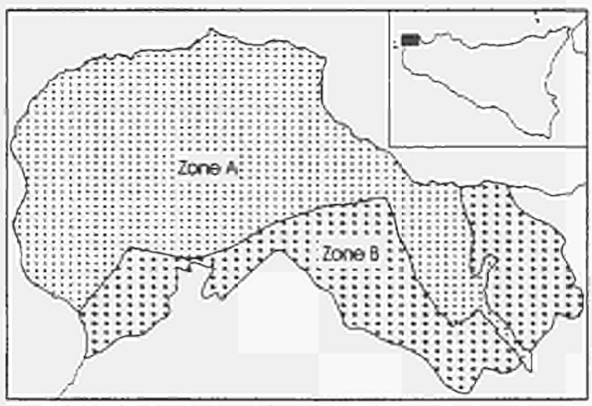

FIGURE 1 - Index Map of "Monte Cofano" Natural Reserve.

TABLE 1 - Scheme of vegetation series of "Monte Cofano" Natural Reserve.

THERMOMEDITERRANEAN DRY XERO-HALOPHILOUS RUPICOLOUS GEOSERIES OF COASTAL CLIFFS
- *Limonium bocconei* (Lojac.) Litard. chamaephytic community
  (*Limonietum bocconei* Barbagallo, Brullo et Guglielmo 1979)
- *Helichrysum rupestre* (Rafin.) DC. var. *cophanense* Brullo chasmo-halophilous community
  (*Crithmo-Limonion* Molinier 1934)

THERMOMEDITERRANEAN DRY XERO-SUBHALOPHILOUS SERIES OF DWARF PALM
(*Pistacio lentisci-Chamaeropeto humilis* sigmetum)
- *Chamaerops humilis* L. and *Pistacia lentiscus* L. maquis
  (*Pistacio lentisci-Chamaeropetum humilis* Brullo et Marcenò 1985)
- Subhalophilous therophytes grassland
  (*Anthemido secundirameae-Desmazerietum siculae* Brullo 1985)

THERMOMEDITERRANEAN DRY CALCARENITIC SERIES OF KERMES-OAK
(*Chamaeropo humilis-Querceto calliprini* sigmetum)
- *Quercus calliprinos* Webb maquis
  (*Chamaeropo-Quercetum calliprini* Brullo et Marcenò 1985)
- *Chamaerops humilis* L. brush
  (*Chamaerops humilis* facies of *Chamaeropo-Quercetum calliprini* Brullo et Marcenò 1985)
- *Coridothymus capitatus* Rchb. f. garrigue
  (*Rosmarino officinalis-Coridothymetum capitati* Furnari 1965)
- *Hyparrhenia hirta* (L.) Janchen steppe
  (*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl.1950)
- Subhalophilous therophytes grassland
  (*Anthemido secundirameae-Desmazerietum siculae* Brullo 1985)

THERMOMEDITERRANEAN DRY-SUBHUMID BASIPHILE OMBROPHILE SERIES OF HOLM-OAK
(*Rhamno-Querceto ilicis* sigmetum)
- *Quercus ilex* L. and *Pistacia terebinthus* L. woodland and bushland
  (*Rhamno-Quercetum ilicis* Brullo et Marcenò 1985
  subass. *pistacietosum terebinthi* Gianguzzi, Ilardi et Raimondo 1996)
- Thorny thickets
  (*Pruno-Rubion ulmifolii* O. de Bolòs 1954)
- *Ampelodesmos mauritanicus* (Poiret) Dur. et Sch. steppe
  (*Helictotricho convoluti-Ampelodesmetum mauritanici* Minissale 1994)
- *Stipa capensis* Thunb. ephemeral grassland
  (*Trachynion distachyae* Rivas-Martinez 1978)

THERMOMEDITERRANEAN DRY XEROPHILOUS RUPICOLOUS GEOSERIES OF WILD OLIVE
(*Rhamno alaterni-Euphorbieto dendroidis* sigmetum)
- *Olea europaea* L. var. *sylvestris* Brot. and *Euphorbia dendroides* L. maquis
  [*Rhamno-Euphorbietum dendroidis* (Trinajstic 1974) Biodi et Gehù 1997
  subass. *euphorbietosum bivonae* (Gianguzzi, Ilardi et Raimondo 1996) Biodi et Gehù 1997]
- *Hyparrhenia hirta* (L.) Janchen steppe
  (*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl. 1950)
- Crassulid therophytes grassland
  (*Sedetum caerulei* Brullo 1975)
- *Lomelosia cretica* (L.) Greuter et Burdet chasmophytic community
  (*Scabioso-Centauretum ucriae* Brullo et Marcenò 1979 subass. *typicum* and subass. *ericetosum siculae*)

THERMOMEDITERRANEAN DRY BASIPHILE SERIES OF HOLM-OAK
(*Pistacio lentisci-Querceto ilicis* sigmetum)
- *Quercus ilex* L. and *Pistacia lentiscus* L. woodland and bushland
  (*Pistacio lentisci-Quercetum ilicis* De Marco et Caneva 1985)
- Thorny thickets
  (*Pruno-Rubion ulmifolii* O. de Bolòs 1954)
- Steppe communities
  (*Hiparrhenietalia hirto-pubescentis* Rivas-Martinez 1978)
- *Stipa capensis* Thunb. ephemeral grassland
  (*Trachynion distachyae* Rivas-Martinez 1978)

MESOMEDITERRANEAN SUBHUMID BASIPHILE OMBROPHILE SERIES OF HOLM-OAK
(*Rhamno-Querceto ilicis* sigmetum)
- *Quercus ilex* L. and *Arbutus unedo* L. bushland
  (*Rhamno alaterni-Quercetum ilicis* Brullo et Marcenò 1985 var. *Arbutus unedo*)
- *Cistus creticus* L. garrigue
  (*Cisto-Ericion* Horvatic 1958)

THERMOMEDITERRANEAN HYGROPHILOUS GEOSERIES OF PONDS
- Submerged-rooted plant community
  (*Ranunculetum baudotii* Br.-Bl. 1952)
- Free-floating surface community
  [*Lemnetum gibbae* (W. Koch 1954) Miy. et J. Tüxen 1960]

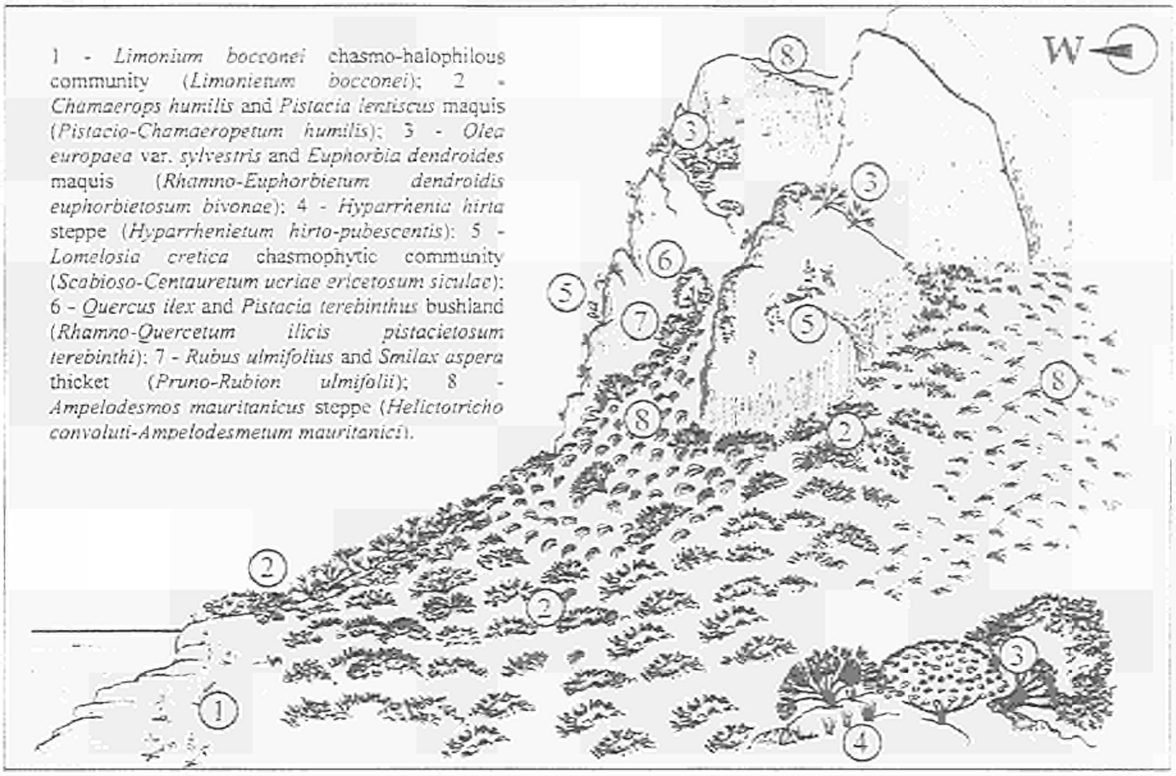

FIGURE 2 - Schematic transect of actual vegetation of "Monte Cofano" Natural Reserve.

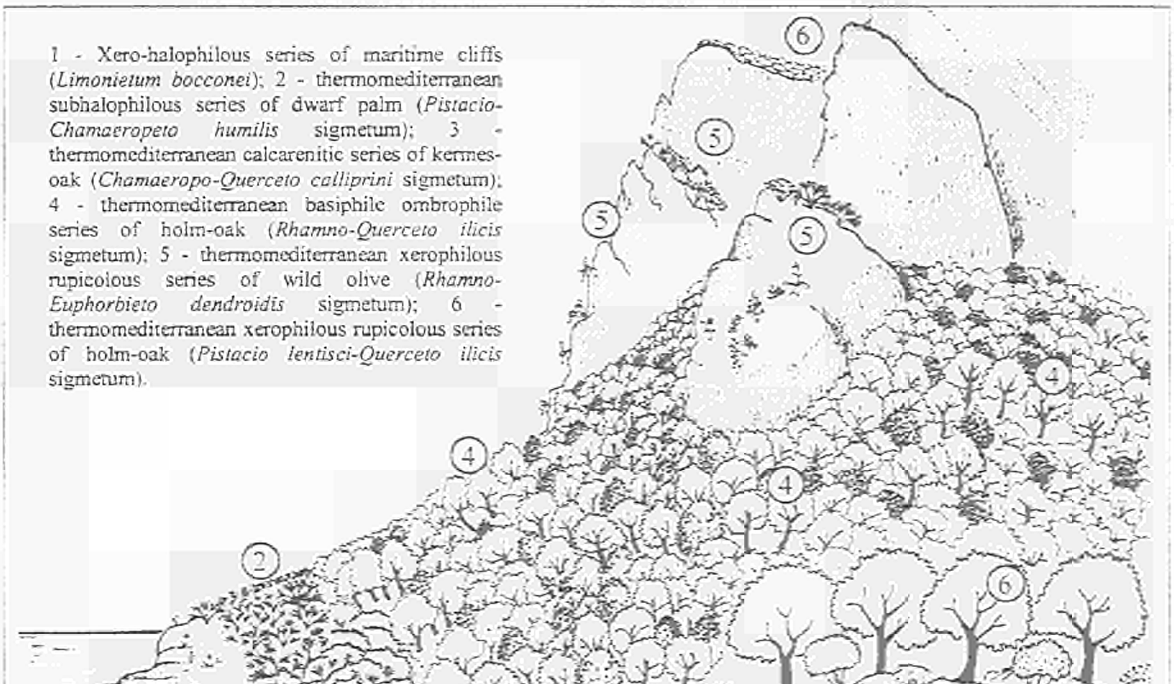

FIGURE 3 - Schematic transect of potential vegetation of "Monte Cofano" Natural Reserve.

"D.A. Territorio ed Ambiente n° 486/44 del 25/7/1997 (G.U.R.S. n° 3 del 16/1/1998, suppl. ord. n° 1)" and it is managed by "Azienda Foreste Demaniali della Regione Siciliana".

From a geological point of view, the Cofano massif consists of Doloarenites and Dolorudites that go back to Upper Trias and Dolomites that go back to Lias-Upper Trias. Calcilutites and Calcarenites (Upper-Medium Cretaceous) are widespread in the inner part of the reserve, while along the western coastal side there are some bioclastic Calcarenites and Conglomerates (Lower Pleistocene-Upper Pliocene) (Abate et al. 1993). From a bioclimatical point of view, the territory has been referred to as the thermomediterranean thermotype and upper dry up to upper subhumid ombrotype (Gianguzzi and La Mantia 2000).

The interpretation and the cartographic representation (1:20000) of different actual and potential vegetation aspects of the protected area are the aim of this investigation. Along the cliffs are present remarkable chasmophytic communities characterized by several endemics linked to hard limestome, while the landscape is characterized by *Ampelodesmos mauritanicus* steppe mixed with *Chamaerops humilis* brush. These communities are secondary aspects, frequently exposed to fire, characterized by low floristic richness. Because of human influence, the areas surrounding "Monte Cofano" are characterized by a diversity which is ecologically lower than the one in the reserve zone.

The syntaxonomical investigations showed the presence of various aspects of vegetation to be referred to as several vegetation series (some climatophilous, others edaphophilous), which were cartographically delimited for a preparatory study. In particular, the synphytosociological study highlighted the vegetation series (sigmeta) listed in Table 1 and represented in Figure 2 and Figure 3. This one could provide a basic ground for the management of the protected territory.

Notes

Financial support by M.U.R.S.T. (ex 60%) is gratefully acknowledged.

References

Abate, B., Di Maggio, C., Incandela, A. and Renda, P. 1993. Carta geologica dei Monti di Capo San Vito (scala 1:25000). Dipartimento di Geologia e Geodesia: Palermo.

Barbagallo, C., Brullo, S. and Guglielmo, A. 1980. Carta della vegetazione di Monte Cofano (Sicilia occidentale). In Collana del Progr. Finalizzato "Promoz. Sulla Qualità dell'Ambiente", s. AQ\1\39. C.N.R. Roma.

Brullo, S. and Marcenò, C. 1985. Contributo alla conoscenza della classe Quercetea ilicis in Sicilia. Not. Fitosoc. 19 (1): 183-229.

Gianguzzi, L., Ilardi, V. and Raimondo, F. M. 1996. La vegetazione del promontorio di Monte Pellegrino; Palermo. Quad. Bot. Ambientale Appl. 4: 79-137.

Gianguzzi, L. and La Mantia, A. 2000. Il paesaggio vegetale. In Gianguzzi, L. and Ottonello, D. La Riserva di Monte Cofano (Sicilia nord-occidentale). Aspetti geomorfologici, naturalistici ed etnoantropologici. In Collana Sicilia Foreste 8: 37-66. Edited by Azienda Foreste Demaniali della Regione Siciliana; Palermo.

Gianguzzi, L., La Mantia, A. and Ottonello, D. 2000. Indagini sinfitosociologiche e cartografiche sulla vegetazione della Riserva naturale orientata di Monte Cofano (Sicilia nord-occidentale). Proceedings of 95th Congress of S. B. I., Messina, 28-30 September 2000.

Mazzola, P., Romano, S. and Cusimano, S. 1984. Monte Cofano: area di interesse biogenetico e fitogeografico in provincia di Trapani. Atti Accad. Sci. Palermo s. 4, 40 (1): 189-209.

Pignatti, S. 1979. Monte Cofano. In AA. VV., Censimento dei Biotopi di rilevante interesse vegetazionale meritevoli di conservazione in Italia. Camerino.

Raimondo, F.M., Fici, S., Gianguzzi, L., Lentini, F., Mazzola, P., Miceli, G., Not, R., Ottonello, D., Romano, S. and Schicchi, R. 1986. Atlante iconografico delle piante endemiche o rare della Riserva naturale orientata dello Zingaro. Edited by A.F.D.R.S.; Palermo.

Raimondo, F.M., Gianguzzi, L. and Ilardi, V. 1992. Inventario delle specie "a rischio" nella flora vascolare nativa della Sicilia. Quad. Bot. Ambientale Appl. 3: 65-132.

Synphytosociological and ecological analysis of landscape applied to the management of protected areas in Sicily. 3. Bosco Ficuzza-Rocca Busambra Natural Reserve

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Abstract
The main results of a synphytosociological study on the landscaspe of "Bosco Ficuzza-Rocca Busambra" Natural Reserve (Mts. Sicani, north-central Sicily), carried out as a basis for the future publication of vegetation map (1:20000), are here presented. Besides the syntaxonomical typification of the studied coenoses, the different series and geoseries have been characterized. The correlation between the thermopluviometric data and the vegetational features showed a remarkable bioclimatical diversification of the territory, with mesomediterranean belt (upper dry, lower subhumid and upper subhumid ombrotype) and supramediterranean belt (upper subhumid ombrotype). This study could provide a basic ground for the management of the protected area.

Keywords: Sicily, Bosco Ficuzza-Rocca Busambra reserve, synphytosociology, phytoecological cartography

1. Introduction

The conservation and the restoration of the landscape represent the first tasks of institutions managing the protected habitats (Natural parks and reserves). From this point of view, the phytosociological method can be used for a territorial planning because it can supply an interpretation of several actual and potential vegetation types. Synphytosociology can be applied to restore scattered aspects of vegetation, to preserve most valuable floristic and phytocoenotic aspects, to plan relative interventations and to chose the best management criteria.
This preliminary study is based on a cartographic representation of the actual and potential vegetation and the bioclimate of the territory of "Bosco Ficuzza-Rocca Busambra" Natural Reserve (Figure 1). It is located in northern part of Sicani Mountains (north-central Sicily).

2. Results and discussion

The Natural Reserve of "Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere, Gorgo del Drago" was established by "D.A. Territorio ed Ambiente n° 365 in 26/7/2000" and managed by Azienda Foreste Demaniali della Regione Siciliana. It is one of the most extensive reserves of Southern Italy, with its 7397 ha: 5333 ha in zone 'A' and 4064 ha in zone 'B'.
The site is considered one of most important regional biotopes, because of biological, natural, environmental and historical values. Many plant species present in the reserve have particular phytogeographic importance (Raimondo, Gianguzzi and Ilardi 1992). The local endemics of this territory are *Armeria gussonei* Boiss., *Valantia deltoidea* Brullo and *Viola tineorum* Erben et Raimondo. Other interesting endemic species are *Centaurea busambarensis* Guss.,

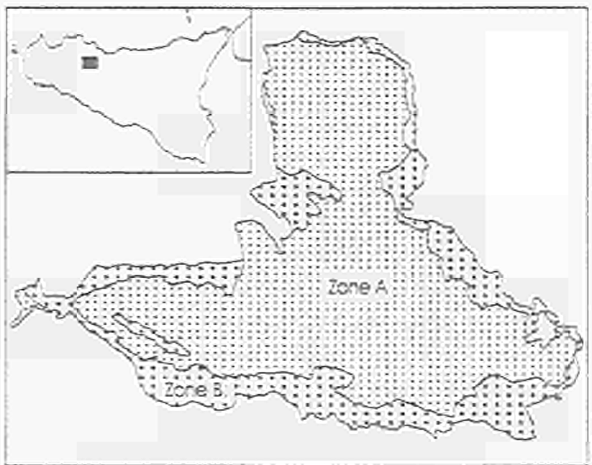

FIGURE 1 - Index Map of " Bosco Ficuzza-Rocca Busambra " Natural Reserve.

TABLE 1 - Scheme of vegetation series of Bosco Ficuzza-Rocca Busambra Natural Reserve.

Vegetation of clayey-flysch substrata

Mesomediterranean dry-subhumid series of thermophilous deciduous oaks
(*Oleo-Querceto virgilianae* sigmetum)

Quercus virgiliana (Ten.) Ten. woodland and bushland
(*Oleo sylvestris-Quercetum virgilianae* Brullo 1984)
Rubus ulmifolius Schott and *Spartium junceum* L. thickets
(*Pruno-Rubion ulmifolii* O. de Bolós 1954)
Ampelodesmos mauritanicus (Poiret) Dur. et Sch. steppe
(*Helictotricho-Ampelodesmetum mauritanici* Minissale 1994)
Abandoned cultivation and fallow land
(*Sisymbrietalia* J. Tx. 1962)

Meso-supramediterranean subhumid series of mesophilous deciduous oaks
(*Querceto leptobalanae* sigmetum)

Quercus leptobalanos Guss. woodland and bushland
(*Quercetum leptobalanae* Brullo 1984)
Crataegus laciniata Ucria thickets
(*Crataegetum laciniatae* Brullo et Marcenò 1984)
Cynosurus cristatus L. pastures
(*Plantaginion cupanii* Brullo et Grillo 1978)

Vegetation of siliceous-arenaceous substrata

Mesomediterranean lower subhumid series of cork-oak
(*Genisto-Querceto suberis* sigmetum)

Quercus suber L. woodland and bushland
(*Genisto aristatae-Quercetum suberis* Brullo 1984)
Calicotome infesta (Presl) Guss. thickets
(*Cisto-Ericion* Horvatic 1958)
Cistus L. sp. pl. garrigue
(*Cisto-Ericion* Horvatic 1958)

Mesomediterranean upper subhumid series of Gussone-oak
(*Querceto gussonei* sigmetum)
Quercus gussonei (Borzì) Brullo woodland and bushland
(*Quercetum gussonei* Brullo et Marcenò 1985)
Cytisus villosus Pourret broom fields
(*Erico-Quercion ilicis* Brullo, Di Martino et Marcenò 1977)

Mesomediterranean dry-subhumid xero-acidophilous series of *Phillyrea latifolia*
(*Myrto-Pistacieto lentisci* sigmetum)

Phillyrea latifolia L. and *Pistacia lentiscus* L. brush
(*Myrto-Pistacietum lentisci* Molinier 1954 em. Rivas-Mart.1975)
Hyparrhenia hirta (L.) Janchen steppe
(*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl. 1950)

Mesomediterranean upper subhumid xero-rupicolous series of holm-oak
(*Querco-Teucrieto siculi* sigmetum)

Quercus ilex L. woodland and bushland
(*Querco ilicis-Teucrietum siculi* Gentile 1969)
Erica arborea brush
(*Erico-Quercion ilicis* Brullo, Di Martino et Marcenò 1977)
Cistus L. sp. pl. garrigue
(*Cisto-Ericion* Horvatic 1958)

Vegetation of calcareous-dolomitic substrata

Mesomediterranean dry-subhumid xero-rupicolous series of wild olive
(*Rhamno-Euphorbieto dendroidis* sigmetum)

Euphorbia dendroides L. and *Olea europaea* L. var. *sylvestris* Brot. brush
[*Rhamno alaterni-Euphorbietum dendroidis* (Trinajstic 1974) Biondi et Gehù 1997]
Hyparrhenia hirta (L.) Janchen and/or *Ampelodesmos mauritanicus* (Poiret) Dur. et Sch. steppes
(*Hyparrhenietum hirto-pubescentis* A. et O. de Bolòs et Br.-Bl. 1950, *Helictotricho convoluti-Ampelodesmetum* Minissale 1994)
Thermophilous chasmophytes community
(*Scabioso-Centauretum ucriae* Brullo et Marcenò 1979)

Meso-supramediterranean subhumid xero-rupicolous series of holm-oak
(*Aceri campestris-Querceto ilicis* sigmetum)

Quercus ilex L. woodland and bushland
(*Aceri campestris-Quercetum ilicis* Brullo 1984)
Thorny thickets
(*Crataegetum laciniatae* Brullo et Marcenò 1984)
Ampelodesmos mauritanicus (Poiret) Dur. et Sch. steppe
(*Helictotricho-Ampelodesmetum mauritanici* Minissale 1994)
Nitrophilous grassland
(*Carduncello-Thymetum spinulosi* Brullo et Marcenò 1984, *Bonannietum graecae* Brullo et Marcenò 1985)
Mesophilous chasmophytes community
(*Anthemido-Centauretum busambarensis* Brullo et Marcenò 1979)

EDAFIPHPHILOUS GEOSERIES

Meso-supramediterranean hygrophilous geoseries of water fringe

Salix pedicellata Desf. riparian woodland
(*Ulmo-Salicetum pedicellatae* Brullo et Spampinato 1990)
Carex hispida community
(*Caricetum hispidae* Brullo et Ronsisvalle 1975)
Nasturtium officinale R. Br.community
[*Helosciadietum nodiflori* Br-Bl. (1931) 1952]

Hygro-hydrophytic geoseries of artificial basins
(*Ulmo-Saliceto pedicellatae* sigmetum)

Salix pedicellata Desf. bushland
(*Ulmo-Salicetum pedicellatae* Brullo et Spampinato 1990)
Phragmites australis (Cav.) Trin. cane beds
[*Phragmitetum australis* (W. Koch 1926) Schmale 1939]
Aquatic vegetation
(*Nymphaeion albae* Oberd. 1957 em. Neushausl 1959)

Xerophilous geoseries of clayey steep slopes

Aster sorrentini community
(*Asteretum sorrentini* Brullo 1985)

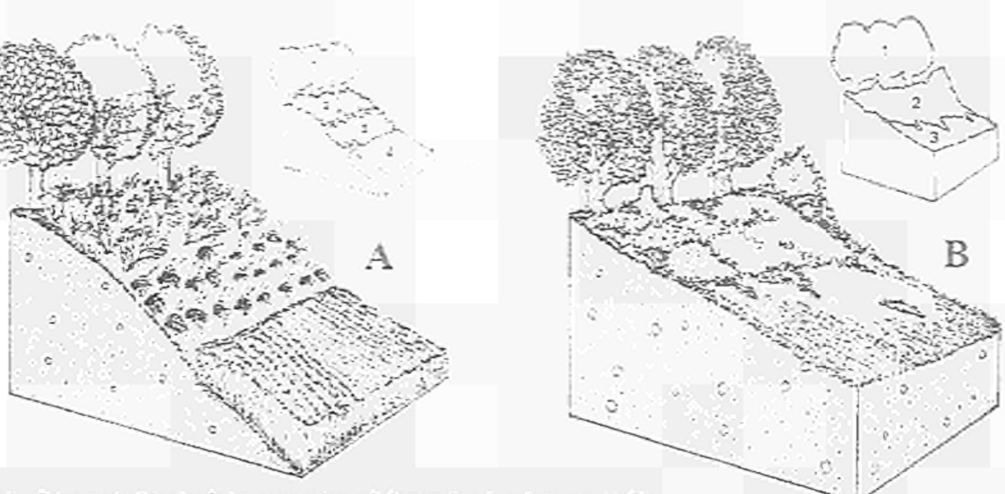

FIGURE 2 - **Schematic block of the vegetation of clayey-flysch substrata (A-B).**
A - Mesomediterranean dry-subhumid series of thermophilous deciduous oaks: 1 - *Quercus virgiliana* woodland and bushland; 2 - *Rubus ulmifolius* and *Spartium junceum* thickets; 3 - *Ampelodesmos mauritanicus* steppe; 4 - Field crops.
B - Meso-suprameditcrranean subhumid mesophytic series of mesophilous deciduous oaks: 1 - *Quercus leptobalanos* woodland and bushland; 2 - *Crataegus laciniata* thickets; 3 - *Cynosurus cristatus* pastures.

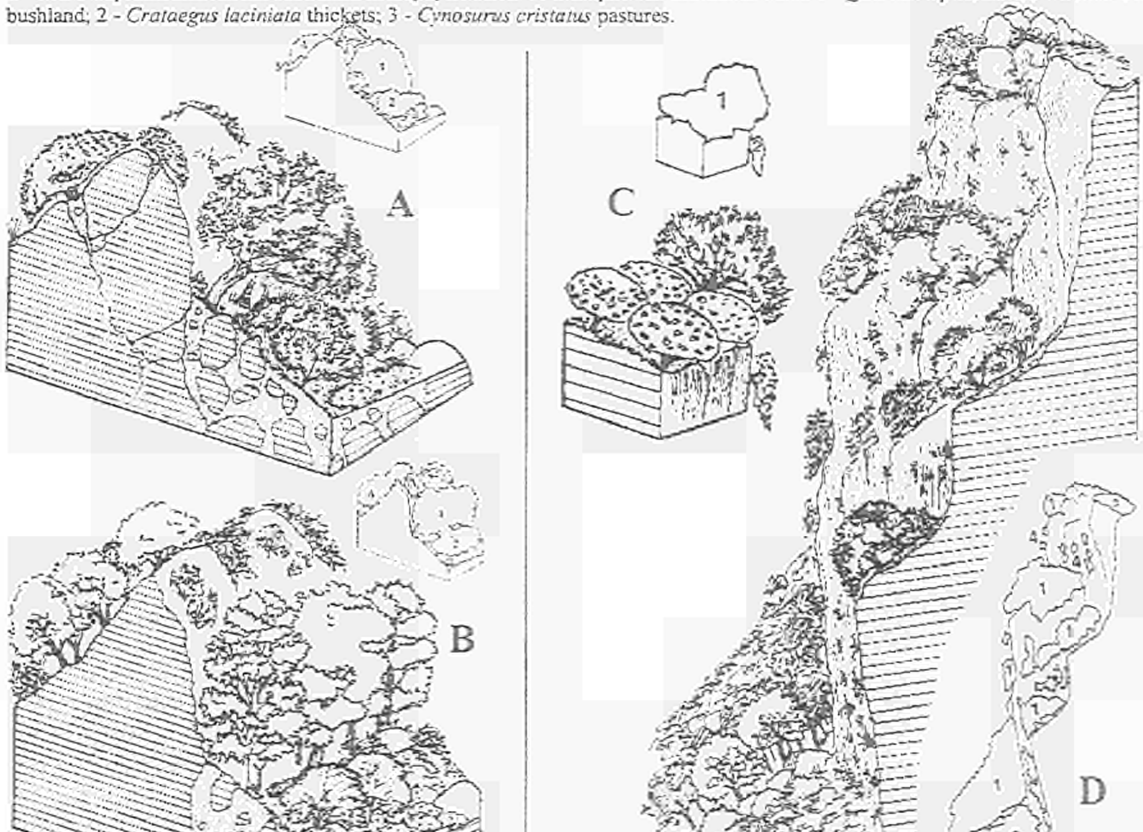

FIGURE 3 - **Schematic block of the vegetation of siliceous-arenaceous substrata (A-B).**
A - Mesomediterranean lower subhumid series of cork-oak: 1- *Quercus suber* woodland and bushland; 2- *Calicotome infesta* thickets; 3 - *Cistus* sp. pl. garrigue. Mesomediterranean dry-subhumid xero-acidophilous series of *Phillyrea latifolia*: 4- *Phillyrea latifolia* and *Pistacia lentiscus* brush; 5 - *Hyparrhenia hirta* steppe.
B - Mesomediterranean upper subhumid series of Gussone-oak: 1- *Quercus gussonei* woodland and bushland; 2- *Cytisus villosus* broom fields; 3- *Calicotome infesta* and *Cistus* sp. pl. garrigue. Mesomediterranean upper subhumid xero-rupicolous series of holm-oak: 4- *Quercus ilex* woodland and bushland; 5 - *Erica arborea* brush.
Vegetation of calcareous-dolomitic substrata (C-D).
C - Mesomediterranean dry-subhumid xero-rupicolous geoseries of wild olive: 1- *Euphorbia dendroides* and *Olea europaea* var. *sylvestris* brush; 2- Thermophilous chasmophytes community.
D - Meso-suprameditcrranea subhumid xero-rupicolous series of holm-oak: 1 - *Quercus ilex* woodland and bushland; 2 - Thorny thickets; 3 - Nitrophilous grassland; 4 - Mesophilous chasmophytes community.

Anthemis cupaniana Tod., *Edraianthus graminifolius* (L.) DC. ssp. *siculus* (Strobl) Lakusic, *Gagea nebrodensis* (Tod.) Nym., *Iberis semperflorens* L., *Minuartia verna* (L.) Hiern ssp. *grandiflora* (Presl) Hayek, *Onosma canescens* Presl, *Vicia sicula* (Raf.) Guss., *Aster sorrentini* (Tod.) Lojac., etc. Remarkable forest species are *Quercus gussonei* (Borzi) Brullo, *Quercus xfontanesii* Guss., *Celtis tournefortii* Lam., *Quercus leptobalos* Guss. *Ilex aquifolium* L., *Prunus cupaniana* Guss., *Crataegus laciniata* Ucria, *Acer pseudopaltanus* L., *Mespilus germanica* L., etc.

The protected area is characterized by an altitude range that runs from about 350 mts. up to the top of Rocca Busambra (1613 mts.), and by a great carbonatic outcrop 15 km long, from West (Pizzo Nicolosi) to East (Pizzo Case), arising from a wide sandish-clayey bank (Giunta and Liguori 1975; Mascle 1979). The geomorphology is quite variable and featured by a hydrographic net from which arise San Leonardo and Belice rivers, two of the most important rivers of western Sicily.

The vegetation map was elaborated through different phases (photo-interpretation, field surveys, on field, etc.). The first data have been reported in a map on a scale of 1:10000 (Gianguzzi, La Mantia and Rigoglioso 2000), and then digitalized and reduced to get as final result on 1:20000.

Apart from the syntaxonomical typification, the investigations showed the presence of various aspects of vegetation to be referred to as several vegetation series (some climatophilous, others edaphophilous), which were cartographically delimited. In particular, the synphytosociological study highlighted the vegetation series (sigmeta) listed in Table 1 and represented in Figure 2 and Figure 3.

As regards the bioclimate, the investigated territory has been referred to as the mesomediterranean belt (upper dry, lower subhumid and upper subhumid ombrotype) while supramediterranean belt (upper subhumid) is limited to top of Rocca-Busambra. The bioclimatical map is reported on a scale of 1:50000, and it is based on Rivas-Martinez (1995) indexes linked to local climate features and to the vegetation series surveyed in the territory. Based on the showed data a vegetation maps (scale 1:10000) and a bioclimatical map (scale 1:50000) will be elaborated as final result of a complete study.

Notes

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References

AA.VV. 2000. Ficuzza. Storia e natura. pp. 1-208. Edizioni Arbor s.r.l.: Palermo.

Biondi, E. 1994. The phytosociological approach to landscape study. Annali di Botanica 52: 135-141.

Gianguzzi, L., La Mantia A. and Rigoglioso, A. 2000. Fitosociologia applicata alla conservazione di aree protette in Sicilia: indagini preliminari per una cartografia della vegetazione del Bosco della Ficuzza e Rocca Busambra (scala 1:20000). Proceedings of 95th Congress of S. B. I., Messina 28-30 September 2000.

Giunta, G. and Liguori, V. 1975. Considerazioni sul significato ambientale e sul ruolo paleotettonico della Rocca Busambra (Sicilia). Boll. Soc. Natur. Napoli 84: 45-59.

Mascle, G. 1974. Carte géologique des Monts Sicani (scale 1 :100000). Officine Grafiche Ires: Palermo.

Mascle, G. 1979. Etude géologique des Monts Sicani. Riv. It. Paleont. Stratigr., Mem. X-VI, 1-431.

Raimondo, F.M., Gianguzzi, L. and Ilardi, V. 1992. Inventario delle specie "a rischio" nella flora vascolare nativa della Sicilia. Quad. Bot. Ambientale Appl. 3: 65-132.

Rivas-Martinez, S. 1995. Classificacion bioclimatica de la tierra. Folia Bot. Matritensis 16:1-29.

Synphytosociological and ecological analysis of landscape applied to the management of protected areas in Sicily. 4. "Vallone Calagna sopra Tortorici" Natural Reserve

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Abstract

A study on the ecological and synphytosociological characteristics of "Vallone Calagna sopra Tortorici" Natural Reserve is here presented. The protected area was recently established for the preservation of one of the most interesting sites of paleoendemic Petagnaea gussonei (Spreng.) Rauschert linked to hygrophilous habitats along streams of Nebrodi Mts. At present the protected area does not include either the spring and the upper part of the stream where it has its optimum. In order to create an ecological continuity with the neighbouring Regional Park of Nebrodi, a new delimitation of this natural reserve is proposed.

Keywords: Sicily, "Vallone Calagna" Natural Reserve, synphytosociology, phytoecological cartography

1. Introduction

A study on the ecological and synphytosociological characteristics of "Vallone Calagna sopra Tortorici" Natural Reserve is here presented. The protected area is located in proximity of the northern side of Nebrodi Mountains (north-eastern Sicily). It was recently established by "D.A. Territorio ed Ambiente n° 365 in 26/7/2000" and managed by Azienda Foreste Demaniali della Regione Siciliana. The protected area is 38,50 ha wide: 24,12 in zone A and 14,38 ha in zone B, occurring on a periannial stream near Tortorici town (Vallone Calagna).

The aim of its establishing is to safeguard the most valuable location of *Petagnaea gussonei* (Spreng.) Rauschert, very interesting paleoendemic entity just limited to some restricted areas within the Nebrodi territory (Figure 1). This species was recorded by Gussone (1827) sub *Petagnia saniculaefolia* and it is considered a relictual element of supposed tertiary origin, representing the only one species that belongs to the genus *Petagnaea* (Apiaceae): from a phylogenetic point of view it is very isolated showing some affinities with entities of genus *Sanicula* L., widespread in Europe, Central-Eastern Asia and North America (Wolf 1913), and *Lereschia thomasii* (Ten.) Boiss. from Calabria (Colombo et al. 1993).

Because of the relictual value and very restricted and scattered distribution, *P. gussonei* population status is considered "very endangered" by several authors (Iriondo et al. 1994).

The species has been included in a risk list by IUCN at Berna Convention and reported in the regional (Raimondo et al. 1994) and national red lists (Conti et al. 1992).

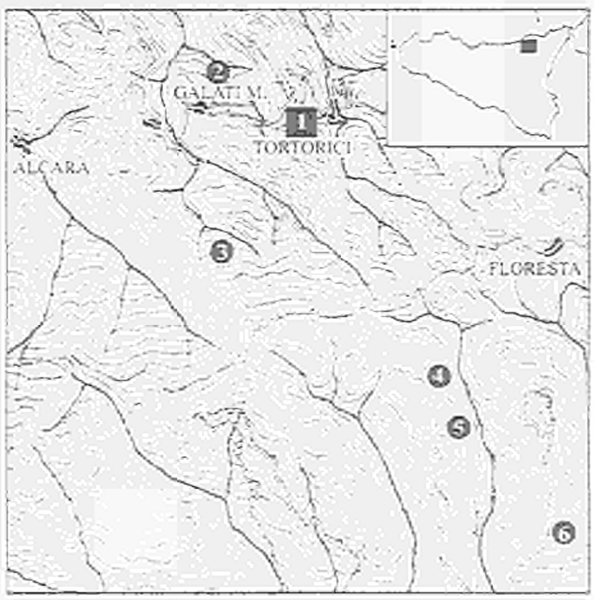

FIGURE 1 - Distribution of *Petagnaea gussonei*: 1 - "Vallone Calagna sopra Tortorici" Natural Reserve; 2 - Torrente Fiumetto (Galati Mamertino); 3 - Contrada Cufò (Galati Mamertino); 4 - Contrada Acquasanta (Tortorici); 5 - Bosco del Flascio (Randazzo); 6 - Boschi di Cannata (Randazzo).

2. Results and discussion

The investigations were focused on the upper course of the Calagna stream, where *P. gussonei* is localized. To estimate conservation status of the species, many field surveys were carried out. They deal with the status of *P. gussonei* population, the habitat features, the possible factors of risk, the phytosociological typification of vegetation and the analysis of dynamic relationships (Figure 2) (Gianguzzi, in press).

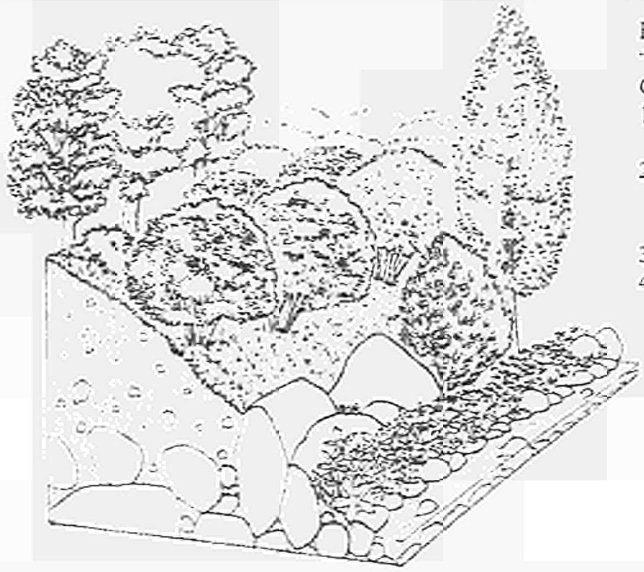

FIGURE 2 - Scheme of vegetation along "Vallone Calagna" Natural Reserve (from Gianguzzi in press, modif.):
1) Petagnaea gussonei community (*Petagnietum saniculaefoliae*);
2) hygrophilous woodland of *Populus nigra* and *Salix pedicellata* (*Ulmo canescentis-Salicetum pedicellatae*);
3) hazel-tree groves;
4) thermophilous deciduous oak woodlands (*Oleo-Quercetum virgilianae*).

The plant features some herbaceous and meso-hygrophilous aspects of vegetation referred to as the *Pegnietum saniculaefoliae* association (Brullo and Grillo 1978) and it includes other entities, very rare in Siciliy as *Lisymachia nemorum* L., *Heracleum pyrenaicum* Lam. subsp. *cordatum* (Presl) Pedrotti et Pignatti, *Rhynchocoris elephas* (L.) Griseb., *Calamintha sylvatica* Brofm. and some bryophytes of phytogeographic interest. The association is characterized by restricted and continuous belts, localized along the streams under *Populus nigra* L. and *Salix pedicellata* Desf. woods (*Ulmo canescentis-Salicetum pedicellatae* Brullo et Spampinato 1990). In the neighbouring areas, some extensive *Corylus avellana* L. and *Castanea sativa* Miller cultivations grow, often mixed with *Quercus virgiliana* (Ten.) Ten. forestal vegetation (*Oleo-Quercetum virgilianae* Brullo et Marcenò 1984).

The field researches showed most interesting aspects of *Pegnietum saniculaefoliae* which are widespread in areas, at present, not included in the reserve, i.e. along the upper part of Calagna stream fed by Patirà spring (790 m. a.s.l.). Apart from some neighbouring springs, the Patirà spring was piped to furnish drinkable water to Tortorici town. Very restricted but continuous *P. gussonei* coenoses are also localized along the streams, running down along the steep slopes at 650-780 m altitude, within hazel-tree wood. The *Petagnietum* phytocoenoses are gradually scattered along the lower part of the stream "Calagna", in particular under 500 m altitude near Tortorici town, where the human action is higher.

Based on the ecological, floristic, phytosociological, synphytosociological and cartographic inedited data, and in order to guarantee a better "in situ" conservation of the species within the "Vallone Calagna" biotope, a new delimitation of the protected area has been proposed (Gianguzzi, in press).

Notes

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References

Brullo, S. and Grillo, M. 1978. Ricerche fitosociologiche sui pascoli dei monti Nebrodi (Sicilia settentrionale). Not. Fitosoc. 13: 23-61.

Brullo, S., Grillo, M. and Guglielmo, A. 1976. Osservazioni ecologiche preliminari su Petagnia saniculifolia Guss., raro endemismo siculo. Giorn. Bot. Ital. 110 (4-5): 293-296.

Colombo, P., Melati, M.R., Scialabba, A., and Raimondo, F.M. 1993 Comparative anatomy and development in Petagnia, Lereschia and Sanicula. Proceedings of VII Optima Meeting. p. 172. Bulgaria 18-30 July.

Conti, F., Manzi, A. and Pedrotti, E. 1992. Libro rosso delle piante d'Italia. 637 pp. Società Botanica Italiana e Associazione Italiana per il World Wildlife Fund: Camerino.

Gianguzzi, L. 1999. Flora e vegetazione dei Nebrodi. Itinerari didattici. 232 pp. Regione Siciliana, Sezioni Operative per l'Assistenza Tecnica n° 5 (Brolo), n° 7 (Castell'Umberto), n° 8 (S. Agata di Militello), n° 10 (Caronia), n° 11 (Mistretta): S. Agata di Militello, ME.

Gianguzzi, L. in press. Osservazioni sulla conservazione in situ di Petagnaea gussonei Spreng.) Rauschert, paleoendemita esclusivo dei Monti Nebrodi (Sicilia nord-orientale). Inform. Bot. Ital.

Gianguzzi, L., Geraci, A. and Certa, G. 1995. Note corologiche ed ecologiche su taxa indigeni ed esotici della flora vascolare siciliana. Naturalista sicil. S. 4, 19(1-2): 39-62.

Gussone, G. 1827. Florae Siculae Prodromus. P. 311. Ex Regia Typographia: Napoli.

Gussone, G. 1842. Florae Siculae Synopsis.I. PP. 306-307. Ex Regia Typographia: Napoli.

Iriondo, J.M., De Hond, L. J. and Gòmez-Campo, C. 1994. Current research on the biology of threatened plant species of the Mediterranean Basin and Macaronesia: a database. Bocconea 4: 5-383.

Raimondo, F.M., Gianguzzi, L. and Ilardi, V. 1994. Inventano delle specie " rischio" nella flora vascolare nativa siciliana. Quad. Bot. Ambientale Appl. 3:65-132.

Rauschert, S. 1982. Nomina nova generica et combinationes novae Spermatophytorum et Pteridophytorum. Taxon 31(3): 554-563.

Wolff, H. 1913. Umbelliferae, Saniculoideae. In: Phlanzenreich, 61(IV, 228): Leipzig.

Forest assessment in view of social and economic sustainability

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ABSTRACT

The impact of forest management activities has highlighted the reality that the sustainability of many ecosystems depends on connections to other systems that extend well beyond individual ownerships, traditional borders of management jurisdiction, and even international boundaries. Natural events or shifts over time could modify locally the type of forest resource that is available, and it should not be assumed that forest ecosystems would not evolve if humans were not part of them. Forest ecosystems are less well adapted to human-caused stresses such as air pollution or global warming and so exposure to these could be expected to adversely affect sustainability. Combinations of harvesting and such stresses may cause ecosystems to react in a manner different than if impacted by purely natural conditions. Since humans and their activities are part of forest ecosystems, it is necessary to account for all activities and ensure that the sustainability of the flow of environmental services is provided by forests institutions.

Keywords: ecosystem management, sustainable forest management

1. INTRODUCTION

Forests are a global resource, and important issues dealing with their use and maintenance cannot be undervalued. Global participation is mandatory, if these resources are to be sustained and equitably utilized. Because of the many functions associated with forests, and the additional complexities of forestry when social and human dynamics are considered, what is truly needed for successfully managing and planning forests is a balanced approach. This approach must ensure that these resources will continue to exist at some acceptable levels for the benefit of current and future generations. This is often referred to as 'sustainable forest management'. It is quite complex, as it seeks to value the forest as a whole, treating all its functions as equally important. This is a challenging undertaking, but it also provides some opportunities to forestry research scientists and institutions. A major challenge with sustainability is that it has many dimensions. A state of sustainable development is achieved only when progress made in one dimension does not compromise progress in any other dimension. For example, activities that enhance the productive function of forests should not reduce the protective capacity of the forests. To do this successfully, scientists need to adopt a multidisciplinary approach; that is to work as a team of people from different disciplines relevant to the question on hand.

2. DISCUSSION

The impact of forest management activities has highlighted the reality that the sustainability of many ecosystems depends on connections to other systems that extend well beyond individual ownerships, traditional borders of management jurisdiction, and even international boundaries.

At its core, ecosystem management assumes that intergenerational sustainability must be a precondition rather than an afterthought, not only for the continued production of "goods" or commodities, but also for the maintenance of critical "services" that ecosystems provide. Society depends on the services that ecosystems provide such as clean air and water, which we value but are not typically given monetary value. These services derive from a diverse array of functions performed by ecosystem.

Throughout history, destruction of forests that led to timber shortages, excessive erosion and soil degradation contributed to the decline of many civilizations, including those in Mesopotamia, Crete, Cyprus, Greece, and Venice (Perlin 1989).

Sustainability is a concept deeply rooted in forestry. The science of forestry was born in Europe in the 18th century because of concerns about the sustained productivity of forests in that continent (Speidel 1972; Huuri et al. 1989). Today, the concept of sustainability is viewed in a much broader ecosystem context that includes preservation of habitat for both game and non-game species, protection of specific threatened and endangered animals and plants, maintenance of esthetic qualities of the forest, and the preservation of native and old-growth forests.

There is currently no universally accepted definition of sustainable forestry, although the concept of intergenerational equity is a common theme of most definitions. The American Forest and Paper Association (AFPA 1999) defines sustainable forestry as the ability to meet the needs of the present society for all the goods, services and processes from the forest, without compromising the ability of future generations to meet their own needs Maser (1994) states that the outcome of sustainable forestry will be the perpetual production of amenities, services and goods for human use.

Demand for forest products and other goods, services and commodities from the forest is related to the size of the world's population which grew by more than 50% between 1970 and 1994 and is currently approaching 6 billion. The global population will increase by an estimated 900 million each decade for the next 50 years with the majority occurring in the developing nations. However, population growth continues in the developed countries.

Global consumption of wood expanded by 36% from 1970 to 1994 reaching a total of approximately 3.5 billion m^3 in response to the increased population (FAO 1997). Slightly more than half of this demand was for firewood with the remainder used for industrial purposes such as lumber and paper production. World income, measured as GDP, increased by 109% between 1970 and 1994 (FAO 1997). It has been estimated that the world's gross domestic product could rise from $20 trillion in 1990 to $69 trillion in 2030 with the most dramatic increase in the developing nations. The per capita consumption of wood and wood-based products will increase as income levels in developing nations rise. However, the developed countries consume a disproportionate amount of the world's industrial wood (FAO 1997) and will continue to do so in the foreseeable future. The continued, albeit slow, population growth in the developed countries is important because of this disproportionate pattern of wood use.

While the demand for forest products is increasing, the area of forests in the world is decreasing. The area of the world's forests, including both natural forests and plantations, was estimated at 3.4 billion ha in 1995 (FAO 1997). Between 1980 and 1995, the world's forests decreased by approximately 180 million ha (FAO 1997), an annual loss of 12 million ha. Over 200 million ha of forest land was lost in the developing countries where exploitation of unmanaged forests continues to lead to deforestation and forest degradation (FAO 1997). This was only partially offset by plantation establishment in the developed world.

Another factor affecting the supply of wood from the world's forest is environmental regulations that restrict harvest. In many parts of the world there are severe restrictions or outright bans on the harvest of natural forests (Ondro et al. 1995; Maclaren 1996). Political and social pressure is mounting to reduce or eliminate timber harvesting in tropical rainforests. For example a consequence of increased emphasis on recreation, visual and cultural resource management, wildlife habitat management, fisheries habitat management and watershed improvement, timber harvest on the national forests in the United States have declined substantially in recent years; from 12.0 billion board feet in 1989 to 3.5 billion board feet in 1997 (USFS 1998). In addition to the absolute decline in volume, the quality of the timber harvested has also declined. Sawtimber volume contributed 80% of the harvest in 1989, but only 20% of the total harvest in 1997.

At the turn of the new millennium the converging trends of increasing world population and the resulting increase in demand for forest products coupled with the decreasing amount of forests in the world is cause for concern. The need for sustainable forestry is clearly recognized. The difficult aspect of this issue is how to balance society's current needs for wood and forest products without compromising future supplies while at the same time protecting and preserving adequate amounts of natural forest ecosystems for other uses.

Unless large areas are dedicated to timber production, growth rates in extensively managed natural forests are not sufficient to sustainably produce the amount of wood and fiber required by society. The worldwide average growth rate in natural stands is around 2 m^3/ha per year (Clawson 1975). At this level of productivity, approximately 1.6 billion ha of forest land are needed to meet the current world demand for wood. However, this amount of land may not be available in the future as environmental restrictions increasingly limit the amount of natural forests available for timber production.

Third-party certification of forest practices and ecolabeling of forest products has been proposed as a method to produce the amount of forest products required by society in a sustainable manner. Forest certification involves the examination of management systems and policies in place as well as on the ground procedures and practices to insure that they comply with a set of established standards. The certification standards, in some cases, discourages or prohibits the use of many forest management practices designed to increase wood production such as plantation establishment, genetic improvement, use of non-native species, fertilization, and herbicide application (Friedman 1999). As a consequence, the growth rates in forests certified may be very low. Growth rates in certified forests of the world currently average only about 0.7 m^3/ha per year (Binkley 1997). At this level of productivity, about 4.7 billion ha of forestland would be required to produce the wood currently consumed worldwide. However, in 1995 there were only about 3.4 billion ha of forestland in the world (FAO 1997).

Several new models incorporating intensively managed plantations in the landscape have been proposed to replace multiple use of extensive natural forests as a management paradigm. The shifting mosaic approach relies on intensive management to create the type of stand conditions required for specific purposes, such as habitat for specific endangered species (Hunter 1990). Creating suitable habitat in one location through intensive management will permit harvest of timber in another area, thus maintaining viable populations of the species dependent on that habitat. A second approach allocates land to various uses, ranging from natural preserves to intensively managed plantations. Concentrating timber production on those sites where intensive management yields high growth rates reduces the amount of land needed to produce the forest products required by society. As pointed out by Sedjo and Botkin (1997), only 150 million ha of intensively managed plantations with a growth rate of 10 m^3/ha per year are needed to meet the world's demand for industrial wood. This represents only 4% of the global forest. Dedicating this area to intensive management will enable large tracts of natural forest to be allocated for other uses such as biodiversity preservation, esthetics and recreation. A consensus appears to be emerging that allocation of forests to specific land uses, including intensive plantation management, is the best way to meet the multiple needs of society for goods, services and processes from the forest in the future (Hunter 1990; Maser 1994; Binkley 1997; Sedjo and Botkin 1997).

Intensive forest management involves the manipulation of soil and stand conditions to ameliorate factors that limit tree growth, and well documentation is available on conifers and hardwoods (Farnum et al. 1983; Allen et al. 1990; Herbert 1990; Neary et al. 1990; Raison and Meyers 1992; Heilman et al. 1995). This differs from extensive management where timber is harvested and the regeneration and development of the subsequent stand occurs without intervention. Silvicultural practices such as site preparation, planting genetically improved seedlings, manipulation of stand density, control of competing vegetation, and fertilization are the tools available to the forester to manipulate site resources. Intensive management is typically associated with plantation management; however, there are many naturally regenerated stands that are managed intensively using treatments such as thinning, pruning, weeding and fertilisation.

Although intensive management clearly increases the growth and yield of forests, the long-term sustainability of intensively managed forests has been questioned. Intensively managed forests must still be managed sustainably; however, in the context of forests zoned into areas of specific land uses, sustainability should be more narrowly focused on two issues: (1) maintain soil quality and long-term site productivity, and (2) minimize offsite impacts so that intensive management does not detrimentally impact adjacent ecosystems. Best management practices (BMPs) and other stewardship practices such as those outlined in the Sustainable Forestry Initiative of the American Forest and Paper Association (AFPA 1999) effectively minimize the offsite impacts of forest management (Neary and Hornbeck 1994).

3. CONCLUSIONS

Forestry has traditionally been relegated to soils that are no longer, or never were, suitable for agricultural uses. These soils are often shallower, rockier, wetter, steeper, sandier, or less fertile than soils used for agriculture production. In many parts of the world, forest plantations have been established on degraded agricultural or pasture soils. The productivity of many of these soils was degraded to the point that they could no longer economically support the production of crops or livestock. The appropriate baseline to judge the sustainability of forest management practices on these sites is the soil quality and site productivity that existed when forest plantations were first established. Because of their degraded condition, intensive management practices such as site preparation, use of improved genotypes and fertilization will be needed to achieve high levels of forest growth on these soils. Forest management should be considered as sustainable on these sites when the baseline level of productivity can be maintained if intensive management inputs are removed. It is not necessary to maintain the higher levels of productivity that are possible under intensive management when the management inputs are reduced.

The key to sustaining soil quality is site-specific management. Site-specific management requires a detailed knowledge of soils as they occur on the landscape and their physical, chemical and biological properties that affect productivity (Stone 1975; Jones 1994). Understanding the processes and properties of a specific soil that affect, and potentially limit, productivity and recognizing soils that are susceptible to management induced changes will enable foresters to develop management regimes tailored to each soil. The structural complexity and diversity of ecosystems directly influence the pattern and rate of many ecosystem processes as well as providing habitat for organisms which maintain important processes. Structural complexity in natural forests includes trees of varying size, condition, and species, standing dead trees, and logs and woody debris on the forest floor, as well as multiple canopy levels and canopy gaps. This structural complexity is critical in providing unique habitats for a large array of organisms, many of which have highly specialized habitat requirements. Some of these organisms carry out key ecosystem functioning. Structural complexity of forests is also itself important in maintaining and regulating processes, such as aspects of the hydrologic cycle.

Ecosystem management concepts applied to forests recognize the importance of compositional and structural diversity to sustainability as well as short-term production of goods and services. Maintenance and restoration of structurally diverse forests are major objectives.

Biological diversity provides for both stability (resistance) to and recovery (resilience) from disturbances that disrupt important ecosystem processes. Diversity-related resistance is particularly relevant to the management of agricultural and forest ecosystems because it can retard the spread of species-specific pathogens and "pest" insects. Although monocultures may result in high levels of production of specific products or resources, they present much higher risks from such infestations than more complex systems.

Long-term adaptations of ecosystems to changes in climate and other environmental variables are strongly dependent upon available biological diversity. Obviously, greater numbers of species and grater genetic variability within species provides for a larger number of biological building blocks for ecosystem response and specie evolution. Long-term pollen profiles suggest that relatively unimportant species restricted to particular microsites during one climatic regime may become important and more widespread as the climate shifts. The reservoir of genetic diversity within individual species and populations is clearly central to their ability to adapt to environmental change. In view of this, focus on so-called "improved" genotypes of crop plants and forest trees has raised concern regarding the loss of genetic diversity that might be important if the same species are to be maintained under future conditions.

The impacts and stresses on forests are a combination of natural and anthropogenic factors such as insects, diseases, fire, harvesting, pollution, land use changes all of which act together over time. The impacts of these activities and stresses also change in time and space while our level of knowledge is insufficient to take the action necessary to ensure sustainable forest management. Many natural impacts do not affect sustainability if not impacting forests beyond the natural limits of variability, because forests have reached some level of adaptation to these stresses. Since it is difficult to define this baseline, or often to recognize it, the human ability to 'manage' forests is consequently limited by these factors. Northern and temperate forests are generally adapted to damage by insects, diseases or weather events, consequently the sustainability of forest resources should not be impaired by these stresses. Natural events or shifts over time could modify locally the type of forest resource that is available, and it should not be assumed that forest ecosystems would not evolve if humans were not part of them. Forest ecosystems are less well adapted to human-caused stresses such as air pollution or global warming and so exposure to these could be expected to adversely affect sustainability. Combinations of harvesting and such stresses may cause ecosystems to react in a manner different than if impacted by purely natural conditions. Since humans and their activities are part of forest ecosystems, it is necessary to account for all activities and ensure that the sustainability of the flow of environmental services is provided by forests institutions.

References

AFPA 1999. Sustainable Forestry Initiative Standard. Principles and Objectives. American Forest and Paper Association: Washington, DC, 5 pp.

Allen, H.L., Dougherty, P.M., Campbell, R.G. 1990. Manipulation of water and nutrients – practices and opportunities in southern US pine forests. For. Ecol. Mgmt. 30: 437-454.

Binkley, C.S. 1997. Preserving nature through intensive plantation forestry: the case for forestland allocation with illustrations from British Columbia. For. Chron. 73: 553-559.

Clawson, M. 1975. Forests for Whom and for What. Johns Hopkins University Press: Baltimore, MD.

FAO 1997. State of the World's Forests – 1997. Food and Agricultural Organization of the United Nations: Rome, 465 pp.

Farnum, P., Timmis, R., Kulp, J.L. 1983. Biotechnology of forest yield. Science 219: 694-702.

Friedman, S.T. 1999. Forest regeneration practices: how regional certification standards compare. J. For. 97: 23-32.

Heilman, P.E., Settler, R.F., Hanley, D.P., Carkner, R.W. 1995. High yield hybrid poplar plantations in the pacific northwest. Pacific Northwest Regional Extension Bulletin PNW356. Washington State University: Pullman, WA, 41 pp.

Herbert, F.R. 1990. Fertilizer/site interactions on the growth and foliar nutrient levels of Eucalyptus grandis. For. Ecol. Mgmt. 30: 247-258.

Hunter, M.L. 1990. Wildlife, Forests and Forestry: Principles of Managing Forests for Biological Diversity. Prentice-Hall: Englewood Cliffs, NJ, 370 pp.

Huuri, O., Huuri, L., Oja, S. 1989. Selostus vuanna 1713 julkaistusta Hannss Carl von Carlowitzin teoksesta Sylvicultura Oeconomica. Metsantutkimuslaitoksen tiedonantoja 323, 140 pp.

Jones, R.K. 1994. Site classification: its role in predicting forest land responses to management practices. *In* Impacts of Forest Harvesting on Long-term Site Productivity, pp. 187-218. Edited by Dyck, W.J., Cole, D.W., Comerford, N.B. Chapman & Hall: London.

Maclaren, J.P. 1996. Environmental effects of planted forests in New Zealand. New FRI Bulletin No. 198. New Zealand Forest Research Institute: Rotorua, 180 pp.

Maser, C. 1994. Sustainable Forestry: Philosophy, Science and Economics. St. Lucie Press: Delray Beach, FL, 373 pp.

Neary, D.G., Hornbeck, J.W. 1994. Impact of harvesting and associated practices on off-site environmental quality. *In* Impacts of Forest Harvesting on Long-term Site Productivity, pp. 81-118. Edited by Dyck, W.J., Cole, D.W., Comerford, N.B. Chapman & Hall: London.

Neary, D.G., Rockwood, D.L., Comerford, N.B., Swindel, B.F., Cooksey, T.E. 1990. Importance of weed control, fertilization, irrigation, and genetics in slash and loblolly pine early growth on poorly drained Spodosols. For. Ecol. Mgmt. 30: 271-282.

Ondro, W.J., Couto, L., Betters, D.R. 1995. The status and practice of forestry in Brazil in the early 1990s. For. Chron. 71: 106-119.

Perlin, J. 1989. A Forest Journey. The Role of Wood in the Development of Civilization. Harvard University Press: Cambridge, MA, 445 pp.

Raison, R.J., Meyers, B.J. 1992. The biology of forest growth experiment: linking water and nitrogen availability to the growth of Pinus radiata. For. Ecol. Mgmt. 52: 279-308.

Sedjo, R.A., Botkin, D. 1997. Using forest plantations to spare natural forests. Environment 39: 14-20.

Speidel, G. 1972. Planung im Forstbetrieb. Paul Parey: Hamburg, 267 pp.

Stone, E.L. 1975. Soil and man's use of forest land. *In* Forest Soils and Forest Land Management, pp. 1-9. Proceedings of the Fourth North American Forest Soils Conference, Montreal, Que. Edited by Bernier, B., Winget, C.H. Laval University Press, Que.

USFS 1998. Changing Economics of the National Forest Timber Sale Program. USDA Forest Service: Washington, DC, 149 pp.

Detection of landscape changes on the former interior German border by Landsat TM data

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Abstract.
The data of satellite remote sensing systems offer a wide spectrum of research and application for the detection of landscape changes. The former interior German border represents an area which is supposed to have experienced considerable landscape changes within the last ten years. Because of safety precautions arranged by the former GDR (German Democratic Republic), there has been a massive effect on vegetation in the immediate area of the demarcation line. Since 1990 these interventions at the ecosystem have been stopped and a natural succession of vegetation was possible.
Land cover changes were documented by the multitemporal analysis of Landsat TM data from 1989 and 1999. Three methods were applied: (1) visual interpretation, (2) digital classification, and (3) calculation of landscape indices. Within ten years, land cover changes can be shown by the application of visual interpretation and digital classification. Landscape indices were calculated for two agricultural and for two forestry-used areas located in the former GDR and the German Federal Republic. At acquisition time, in 1989, remarkable differences in landscape structures emerged between the two regions, but did not change significantly until 1999.
Classification accuracy was mainly affected by mixed pixels. They appeared on all close transitions of land cover classes and were mainly caused by the relatively low spatial resolution of the utilized sensor. By using Landsat TM Data, one receives reliable evidences especially in areas in which already advanced stages of succession can be found.

Keywords: landscape changes, Landsat TM data, visual interpretation, digital classification, landscape indices

1. INTRODUCTION

The basis for the detection of landscape-changes is the assessment of an existing land cover at different times. Traditionally, the extraction of the required information took place by means of field studies and mapped outputs. The application of this approach is limited to small areas, due to economic considerations. For the detection of land-cover changes over large areas, remote sensing techniques have been described as an operational tool (Quiel 1986; Izuchukuwu 1994). However, they cannot replace field assessments in total but help to reduce the number of field observations needed for inference. This paper presents an application of a combined remote sensing/ field assessment approach to detect landcover changes at the former interior border of Germany.

The former interior German border was 1393 km long and represents an area, that was supposed to have experienced considerable changes through the dismantling of the border installations during the last decade. The past massive influence and control of the landscape surrounding the former border area e.g. with chemical and mechanical ground cultivation led to a durable and visible change of the natural landscape. Along an approximately 100 meters wide strip all vegetation was premanently removed by ploughing. After the discontinuation of these measures in 1989 and the dismantling of the border installations from 1990 on, the natural vegetation could regenerate in the area of the former border-strip. For the study an area of approximately 600 km² located in the south east of Germany at the Thuringian-Bavarian border (Fig. 1). It is a low mountain landscape, covered predominantly by coniferous trees.

FIGURE 1: Location of the area of interest

2. Objective

The object of the study was to study the potential of multi-spectral satellite imagery to detect possible landscape changes, that have occured in the time period between 1989 and 1999 at the immediate border strip. The sensor chosen was Landsat TM. The study focuses on the application of three different methods of digital image analysis:

(1) Visual interpretation

(2) Digital classification

(3) Calculation of landscape indices

Two Landsat TM scenes acquired in 1989 as well as in 1999 were utilised as data source and colour air-photographs from the year 1993 were at disposal. In order to get reliable results, a radiometric and geometric correction of the remote sensing data is necessary. Due to the application of the three methods mentioned above, the current state of the land cover for the two occasions were recorded. A multi-temporal approach was used to detect changes in the landscape over a period of 10 years.

3. Methods

Image pre-processing started with the application of a simple approximation procedure according to HILDEBRANDT (1996) to eliminate the not object induced scatter-light in both satellite scenes.

In a next step the images were georeferenced. For the TM-Scene acquired on July 7th 1989, twelve reference points were identified in the image by means of a topographical maps (1:25.000). With a second order polynomial transformation the iamge was georeferenced using the Nearest Neighbour Resampling. For the Landsat scene acquired in 1999, an image to image geocoding was performed utilizing the scene already geo-referenced. The average RMS-errors at the reference points range from 28 m (0,9472) to 0,006 m (0,0002) and are therefore in the acceptable magnitude of subpixels. The Landsat scene of July 7th, 1989 was used to geo-reference the air photographs included into the evaluation by an the image to image-procedure as well.

3.1 Visual interpretation

In order to optimise the data quality of the remote sensing products, different image enhancement techniques (e.g. generation of the NDVI, Principal components transformation) were applied before the visual interpretation was undertaken. The optimal band combination with respect to the objectives of the analysis was determined by the wide range of spectral bands that were produced.. Afterwards, the represented image contents could be interpreted visually on basis of the spectral reflection characteristics of objects of the earth surface. This approach facilitated a a first glance on the situation of both acquisition times.

3.2 Digital classification

Another approach utilised is the use of digital image analysis. In order to extract as much information as possible about landcover, supervised classification was applied. Object classes were defined and training areas were delimited in colour air-photographs. The system-corrected, radiometric enhanced, multispectral bands of the Landsat TM-acquisition were included into the subsequent spectral signature analyses. The objective of these analyses is primarily the selection of the spectral band best-suitable for the classification. Furthermore, it should be studied, whether the defined object classes can be separated from each other by the spectral information and a convenient classification-result can be expected. Among the alternatives that are offered by ERDAS IMAGINE (Erdas 1997) the following three were chosen: (1) calculation of the Jeffries-Matusita distance, (2) check of classification accuracy of the utilized training areas and (3) evaluation of the signature ellipses for certain band combinations. As classification algorithm, Maximum-Likelihood-Classification was selected because it is has been described to be robust even for heterogeneous data (Bähr 1991). The classification was followed by smoothing the generated image by using a majority filter with a matrix size of 3x3 pixels. In order to check the correspondence of the results with the real situation, twenty reference points per class were defined in air-photographs and the true class assignment was determined.

As for the second occasion (1999) a-aerial photographs were not available the selection of training areas had to be realised by a modified procedure. The training areas, in which land cover changes occured between both occasions were first identified by a binary mask. The differences of the brightness values within a band were calculated for both occasions, followed by overlaying the binary mask over the already existing the training areas. Areas that showed no changes, were integrated without changes into the new classification. Areas, in which changes occured, were verified by field visits and the visual interpretation of the satellite scene. The efforts for the acquisition of new training areas by means of field studies could be reduced considerably by the applied methods, as it was possible to focus on areas with land cover changes. The actual classification process proceeded analogously to the classification applied for the first occasion. For the verification, the image products of the visual interpretation were consulted in this case.

3.3 Calculation of landscape-indices

Landscape-indices are statistical measurements, which help to grasp the structural diversity and nature proximity of ecosystems quantitatively. Classifications such as obtained by remote sensing represent an ideal data basis for the calculation of these landscape measures. From the numerous indices, that have been described in the literature and that are available in the FRAGSTATS software package (McGarical and Marks 1994) altogether six were selected, which are supposed to be suitable for the characterisation of the landscape. (e.g. average size of landscape element, edge density). These indices were calculated for four selected areas on both sides of the former border: two areas were mainly covered by forests and two by agricultural land. The evaluation was realised by mono - and multitemporal approches. As the investigation of individual object classes would have been beyond the scope of this study, only the selected landscape section was characterised as an interrelated unit.

4. Results

4.1 Visual interpretation

Figure 2 presents the Landsat TM scene from 1989 as a simulated colour- infra-red image., The extended forests, which virtually stretch over the entire image, are remarkable. The border-strip that was kept free of vegetation can clearly be identified as a continuous light-green line. Merely in the left part of the image a vegetation covered border strip can be assumed due to the light-red colouring. Taking the scene from 1999, it is remarkable, that the border-strip can still be recognized over large areas. However, in comparison to 1989, it is less obvious and partly red-coloured, i.e covered by vegetation. This indicates a change of conditions between the two considered occasions.

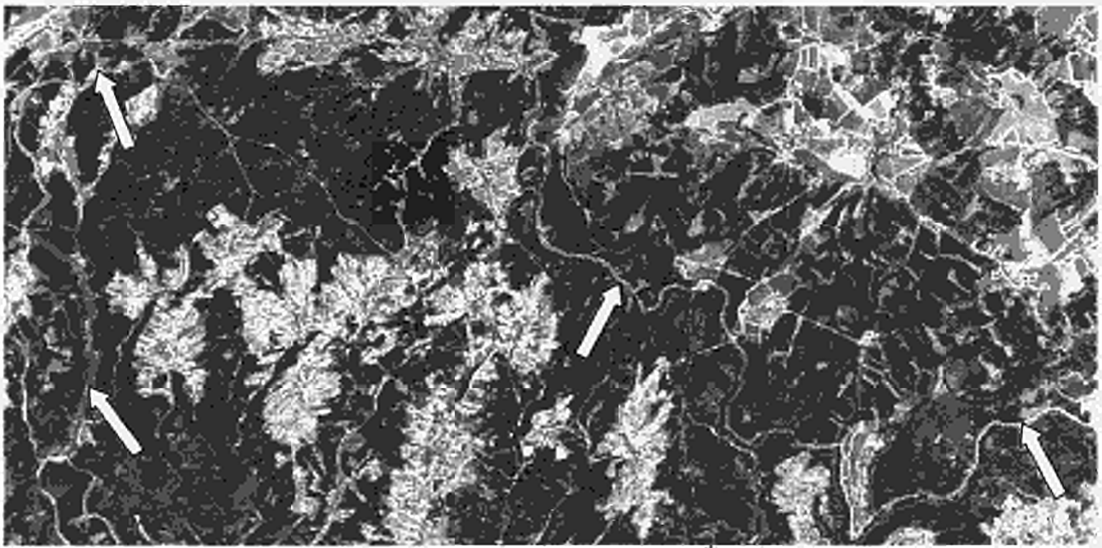

FIGURE 2: Representation of the Landsat TM-Scene of July 7th 1989 as simulated colour- infra-red image

4.2 Digital classification

The following object classes were defined by means of air-images and spectral signature-analyses:

(1) coniferous forest

(2) deciduous forest

(3) young stands

(4) sparse natural cover

(5) non-wood land

The classification results for the first occasion shows, that the border-strip differs clearly from its surroundings. Almost in its entire course, it is classified as non-wood land. Merely in a short section, sparse natural cover or deciduous forests can be observed. In immediate proximity of the border-strip, sparse natural cover is classified in wide parts. The classification accuracy determined by twenty reference points per object-class amounts to an overall accuracy of approximately 75 percent.

The best results were found for the classes "coniferous forest", "deciduous forest" and "young stands". Most classification errors emerged at the class „sparse natural cover". In this class the number of the reference points, which were classified as "coniferous forest", is unexpectedly high

The methodology used for the classification of the 1999 scene resulted in areas, in which processes of succession have appeared (presented in red) , are represented red in the produced binary mask. Regions, on which vegetation cover was removed, are coloured blue (Fig. 3).

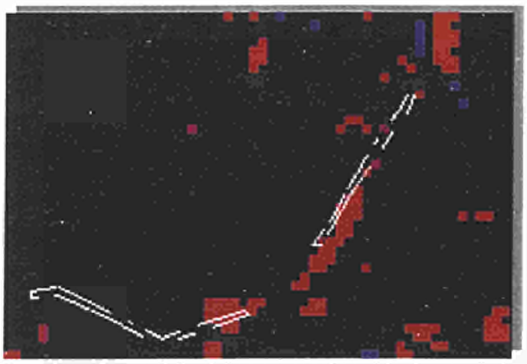

FIGURE 3: Overlapping of the binary mask with the training areas of 1989

The classification results show, that the border-strip is not longer classified as non-wood land completely. In some areas, a succession can therefore be proven by classification. the results of the multitemporal analysis indicate, that this is mainly due to a development from non-wood land to sparse natural cover (Fig. 4). In rare cases a change from non-wood land or sparse natural cover to young stands occured. Looking at the entire border-strip, it is obvious that in wide parts no changes have occured in the time interval considered. This may be partly caused by long-term effects initialised by the intensive anthropogenic measures applied to keep the former border free of vegetation.

The overall classification accuracy obtained be digital classification was approximately 88 percent, which was a clear improvement in contrast to visual interpretation .

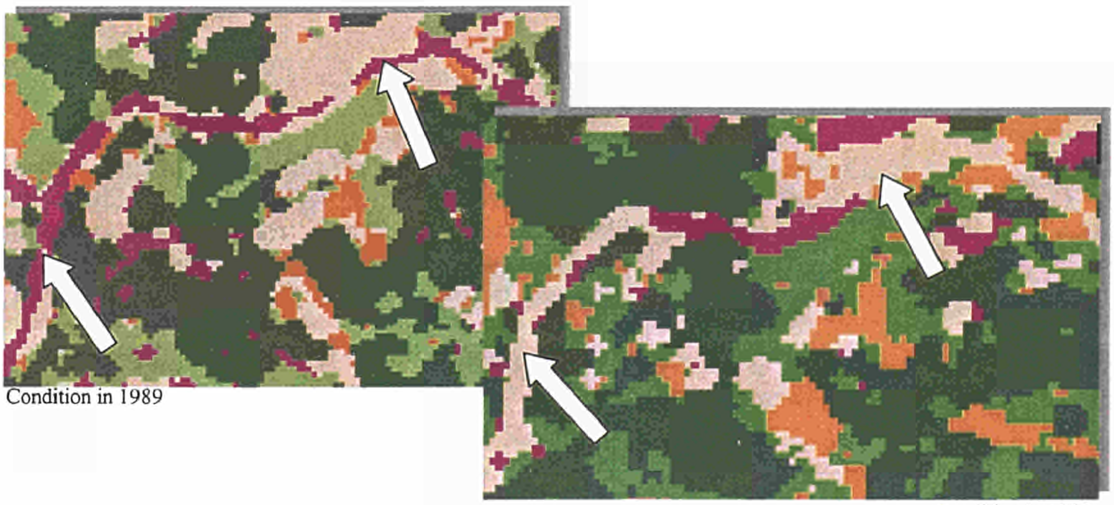

FIGURE 4: Comparison of both classifications; changes from non-wood land (magenta) to sparse natural cover (brown)

4.3 Application of landscape-indices

The application of landscape indices showed that agricultural land characterised by large patch sizes dominates the landscape of the former GDR (average size approximately 6 ha). The landscape of the former FRG is characterised by a multitude of small areas, which have an average size of roughly 1 ha. The largest landscape elements in the former GDR amout to an average size of 17 hectares and are more than twice as large as the largest patches in the former FRG. This is also reflected in the two edge measurements.

The edge lengths or rather the edge densities are with 45.916 meters and 365 m/ha considerably higher than in the former FRG. A similar situation is also to be seen at the selected forested areas. At the multitemporal comparison at both occasions studied considerable differences hardly occur. The landscape structure did not change essentially over a time period of 10 years on both sides of the former border.

TABLE 5: Comparison of the calculated landscape indices for the agricultural used areas

	1989		1999	
Landscape index	Former GDR	BRD	Former GDR	BRD
Average area, covered by the largest landscape element	17 ha	7 ha	17 ha	10 ha
Number of landscape elements per 100 ha	34	92	22	64
Average size of landscape element	6 ha	1 ha	6 ha	1 ha
Total edge length	17784 m	45916 m	16182 m	33759 m
Edge density	157 m/ha	365 m/ha	138 m/ha	272 m/ha
Double logarithm of the fractal dimension	1,13	1,32	0,96	1,30

5. Conclusion

The current study describes the application of different analysis approaches for Landsat TM data. The main objective was to survey landscape changes in the area of the former interior German border. An approximately 600 km² large region was selected as test site. For the two occasions (1989 and 1999) current state and changes of landscape patterns were assessed by three approaches: (1) visual interpretation, (2) digital classification, (3) calculation of landscape indices.

The satellite scenes were preprocessed and disturbing atmospheric influences were eliminated by using a simple approximationprocedure. Especially multitemporal analyses render a normalization of the incidence angel of the sun is essential. Several normalisation models are available. However, as many of the required model parameters at acquisition time were not available, none of those models could be applied. and a non-optimal data basis for image processing has to be accepted. The resulting effects have to be identified in the results of visual interpretation as well as in digital classification. For example, in the classification result, pixels representing a non-wood area are classified as coniferous forest. Due to the application of the Lambertian reflectance model, the topographical effect can be normalized and such classifications errors can be avoided.

In georeferencing the Landsat scenes, it was difficult to find enough reference points. Although the achieved geometric error is still in the range of sub-pixels, the accuracy can be increased by enlarging the number of reference points. This is especially valid for referencing the air-photographs. Due to an appropriate geometric correction, spectral signatures can be produced. Those can better be separated than reflectances containing the reflection of different object classes because of bad georeferencing.

The results of visual interpretation are acceptable in both cases. Due to the late acquisition time (September 13th) of the Landsat scene from 1999, minor disturbances occurred. These caused a poorer differentiation than a scene from July 1999 would have caused. Unfortunately, such scenes were not available because of bad weather conditions.

Mixed pixels have the most decisive influence on the classification. They frequently occur at the transitions of different land cover types, for example at forest edges. The pixels' brightness values contain reflection portions of different object classes caused by the spatial resolution of the sensor. Especially in situations where successions have to be monitored, continuous transitions occur between the different succession stages. Non-wood land is mostly settled from its edges. Because only three to four pixels cover the width of the border strip, it is almost impossible to prove a succession that progresses slowly from the edges to the middle of the strip. In early stages of succession, the brightness value is dominated by soil reflection. Therefore, areas covered with a few trees are classified as non-wood land. A succession or a land cover change can be proved only in later stages, when the reflection is characterized by vegetation. This could be one reason for classifying wide areas of the border strip as non-wood land. During the validation in the field, young stands were found close to the edge, while in the middle of the strip non-wood land dominated. This holds true for more locations of the border strip than were classified as non-wood land. An other cause for misclassifications is presumably the intensive anthropogenic influence on vegetation before 1989. Soil cultivation and application of herbicides nowadays still prevent the development of natural vegetation. This hypothesis can be verified by field studies. Figure 6 presents an example, showing the development of young stands. While on steep slopes the anthropogenic measures could not be as intensive as on flat terrain young trees can be found here but not on a flat area that is several 100 m away.

The application of hyperspectral data presents an approach to reduce the problems caused by mixed pixels (Köhl and Lautner 2001). Compared to multispectral sensors these data differ in the large number of recorded wavelengths. Using the procedures of spectral analysis, the proportion of cover classes per pixel can be estimated and important information for the description of ecosystems can be produced.. Especially for mixed pixels the extracted information content and the classification accuracy can be significantly improved.

The detail of classifications of the Landsat images in the test area were limited, as it was not possible to separate deciduous forests with regard to agricultural used areas due to similar spectral features and settled areas were not defined as an own object class and thus not excluded from the classification.
The classification accuracy and the automatic separation of agricultural areas could be improved by utilising a scene acquired during winter (for example October). Furthermore, the integration of non spectral data could improve the forest-non-forest separation.

FIGURE 6: Tree succession on flat (left) and steep (right) terrain

The calculation of landscape indices, using the program FRAGSTATS caused - with one exception – satisfactory results. Especially the results obtained by visual interpretation – referring to landscape structures - could be confirmed. Contradictory results occurred with the application of the index "double logarithm of fractal dimension" regarding the selected forest areas, which is obviously caused by the low number of the respective landscape elements.. Further research will concentrate on the application of landscape indices on both sides of the former interior German border.

References

Albertz, J. 1991. Grundlagen der Interpretation von Luft- und Satellitenbildern: Eine Einführung in die Fernerkundung. Wiss. Buchgesellschaft: Darmstadt, pp. 93-153.

Bähr & Vögtle. 1991. Digitale Bildverarbeitung. Wichmann: Karlsruhe.

Boardman, J.W., Kruse, F.A. 1994. Automated spectral analysis: A geologic example using AVIRIS data, north Grapevine Mountains, Nevada: in Proceedings, Tenth Thematic Conference on Geologic Remote Sensing, Environmental Research Institute of Michigan: Ann Arbor, MI: 407-418.

Bodmer, H.C. 1993. Untersuchungen zur forstlichen Bestandeskartierung. Professur für Forsteinrichtung, ETH Zürich.

Csaplovics, E. 1992. Methoden der regionalen Fernerkundung: Anwendungen im Sahel Afrikas. Springer: Berlin, Heidelberg, pp. 149-183.

Erdas Field Guide. 1997. Erdas International, Telford House, Fulbourn, Cambridge CBI 5HB, England.

Gangkofner, U. 1996. Methodische Untersuchungen zur Vor- und Nachbereitung der Maximum Likelihood Klassifizierung optischer Fernerkundungsdaten. Münchner Universitätsschriften, Band B24, Institut für Geographie der Universität München.

Hildebrandt G. 1996. Fernerkundung und Luftbildmessung. Wichmann Verlag, 30-69, 415-574.

Izuchukuwu I. J.1994. Multitemporale Satellitenbild-Auswertung zur Erfassung von Landbedeckungs- und Landnutzungsänderungen in der Sahelzone in Westafrika. Diss. Universität Hannover.

Kellenberger, T. 1996a. Erfassung der Waldfläche in der Schweiz mit multispektralen Satellitenbilddaten. Remote Sensing Series, 28, Geographisches Institut der Universität Zürich.

Kellenberger, T. 1996b. Classification of Temperate Forests in Switzerland with Multispectral Data: Effects of Ground Thruth and Satellite Data Scaling on Classification, in: P.J. Kennedy (ed.): Application of Remote Sensing in European Forest Monitoring, EC-Joint Research Center, EUR 17685 EN: 421-428.

Klenke, M. 1999. GIS-gestützte Landnutzungsklassifikationen auf Grundlage von Daten passiver und aktiver Fernerkundungssensoren zur distributiven Flusseinzugsgebietsmodellierung. Jenaer Geogr. Schriften, Band 8, Friedrich-Schiller-Universität Jena, Institut für Geographie.

Köhl, M., Lautner, M. 2001. Erfassung von Waldökosystemen durch Hyperspektraldaten. Photogrammetrie – Fernerkundung – Geoinformation, Heft 2: 107 – 117.

McGarical, K., Marks, B.J. 1994. Fragstats. Spatial pattern analysis program for quantifying landscape structure. Version 2.0, Corvallis.

Pieters & Englert. 1993. Remote Geochemical Analysis: Elemental an Mineral Content. Cambridge University Press: New York.

Richards, J. A., Xiuping, J. 1999. Remote Sensing Digital Image Analysis: An Introduction, Third Edition, Springer Verlag: New York.

Ecological land classification for root and butt rots susceptibility: an application of Geographic Information Systems in the Alpine region

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ABSTRACT
A GIS (Geographical Information System)-modelling framework was developed for the assessment at regional scale of the environmental impact of root and but rots caused by Heterobasidion annosum. A method is presented for planning silvicultural management in order to reduce the damaging effects of the pathogen. The system integrates within a GIS interface, data on H. annosum's biological requirements, silvicultural and stational data. The necessary model input data of the latter ones were extracted by an ArcView-GIS from the available digitised forest map databases where geographical, silvicultural, climatic, pedological, anthropical and historical data were joined at the Woodland Management Plans (WMP) compartment level. The cartographical results presented by GIS illustrated root and but rots susceptibility of about 257.000 hectares of conifer forest in Trentino, Italian Alps. In this application, GIS is considered as a screening tool in a WMP compartments selection process to narrow the number of susceptible sites, subsequently leading few sites for detailed investigation. Preliminary ranking for a group of potential susceptible WMP compartments was done on the basis of simple calculations. Results revealed the potential for developing a decision support system based on H. annosum loss potential indices, although further validation of this field scale model at the WMP compartment level is needed. From a preliminary H. annosum incidence data in Trentino, the presence and the damages caused by this fungus appears surprisingly high. The modelling framework assessed the vulnerability for H. annosum rots of a pilot regional study in Trentino. The resulting vulnerability map might be a helpful tool for policy makers, forest managers and stakeholders in diversify forest structure as a function of the environmental traits to enhance forest stability.

Keywords: GIS, *Heterobasidion annosum*, root rots, Trentino, susceptibility

1. Introduction

Root and butt rots in forest of conifers are mainly caused by the fungal pathogen *Heterobasidion annosum*. This basidomycetes is considered to be the most limiting single disease in coniferous forest throughout the Northern Hemisphere (Shea 1971). In South Tyrol (East Italian Alps) the attacks of this pathogen were observed in 24%, out of 214 forest sites representative of the province. The *H. annosum* incidence in this Alpine environment increased proportionally with the forest age and was ranging from 9.5%, in the 40-70 years old sites, to more than 50%, in the over-mature sites with 160 years old trees (Anselmi and Minerbi 1989). From a recent field survey study focused on the presence of this fungus in Trentino province it seems that the South-Tyrolean data are even too prudential in terms of infection estimation and that the situation might be more serious (unpublished data).

More than 55% of the whole Trentino province land (620668 ha) is covered by forests (344630 ha) and about 78% of them (268800 ha) are constituted by high forest. The conifers represent almost the totality of the high forest of Trentino with about 95.4% (257000 ha) of the total high forest surface (PAT Vademecum 2001). Norway spruce (*Picea abies* Karst.) represents 62.2% of the all conifers present in the Trentino and the timber year harvesting of this species in Trentino represent about 28% of the whole national spruce harvesting (La Porta 1999). Norway spruce is also one of the most susceptible host for *H. annosum*, and as a matter of fact, a particular biological species of *H. annosum* specialised to attack Norway spruce was recognised by Korhonen (1978).

In this scenario we used a GIS approach to obtain a preliminary ecological land classification for susceptibility to *H. annosum* of spruce forest in Trentino.

2. Material and methods

In this study the main environmental and biotic factors affecting the disease were taken into account. These factors were used as selection filters on the basis of the Woodland Management Plans (WMP) compartments map organised by Forest Service (PAT-SF) and by the SIAT (Information System Land Environment) of the Autonomous Province of Trento who made them available in digital format for environmental technicians and for Research Institutes.

For each compartments, a homogeneous section of wood with an average surface of 16 ha, a database was associated with about 120 different environmental, dendrological and silvicultural parameters. These data are collected by field surveys and regularly updates every ten years following standard criteria.

Eight parameters were used as filter to select the susceptible WMP compartments to annosum root and butt rots. These parameters were the following: presence of high forest, presence of Norway spruce higher than 95%, 300 m distance from pasture land, phytoclimatic belts outside *Picetum,* belonging to an adult or mature structure type, fresh and humid soil condition, calcareous soils and organic matter (Korhonen and Stenlid 1998).

The total number of WMP compartments on which was performed the selection was 14223.

Overlay of maps and data analyses were performed by means of ArcView GIS (ESRI, USA).

3. Results and discussion

By means of the above mentioned eight parameters was possible to select 555 WMP compartments out of 14223 (Fig. 1).

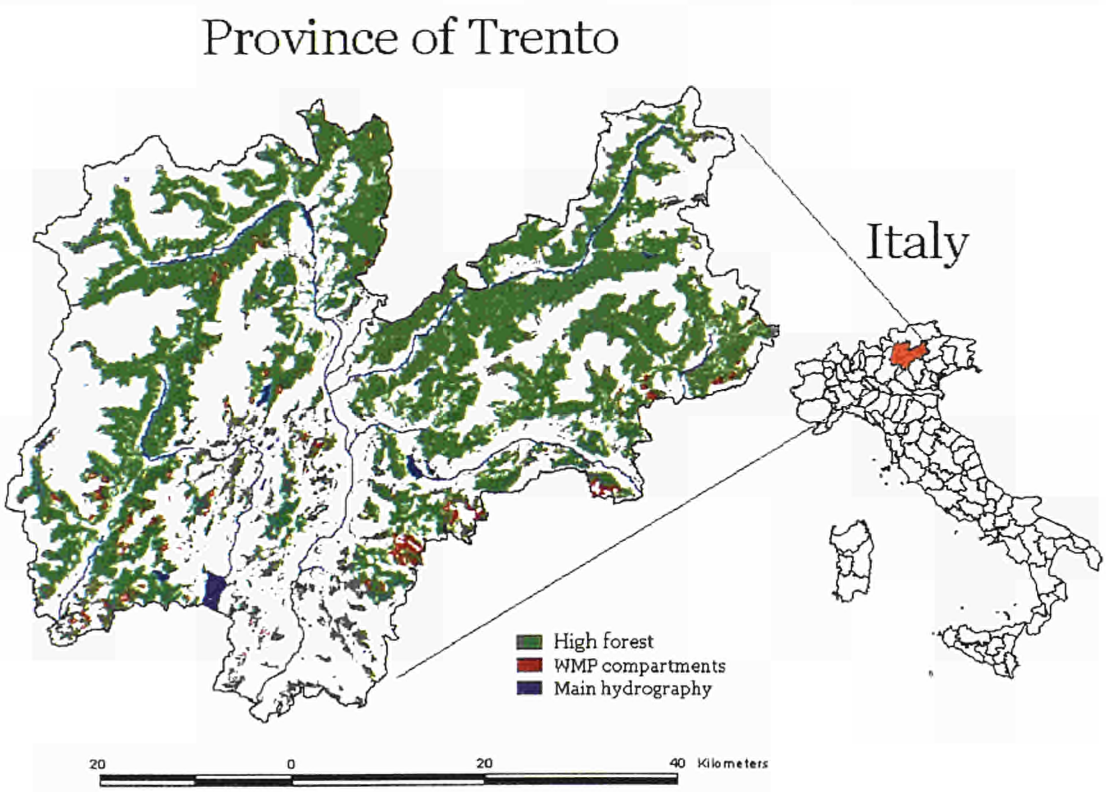

FIGURE 1 – The 555 Woodland Managed Plan spruce compartments susceptible to annosum root and butt rots selected by means of eight environmental, silvicultural and ecological parameters.

Fig. 2 shows the progressive number of WMP compartments that are chosen during the selection process by each parameter. The buffer of 300 m around pasture lands selected 44% (3651 out of 8249) of the Norway spruce compartments. The former pasture and agricultural soils are considered the most hazardous sites for annosum root rots. In Trentino is quite rare the occurrence of forest plantation on former arable land. However, Norway spruce compartments which are incident to the buffer pasture land are putatively very susceptible to *H. annosum* attacks both in case of current pasture practice inside the forest, because the damages caused by the cows to roots and barks, and in case of forest planted on former pasture land where the reduction of soil antagonistic microrganisms decreased the natural control of *H. annosum*.

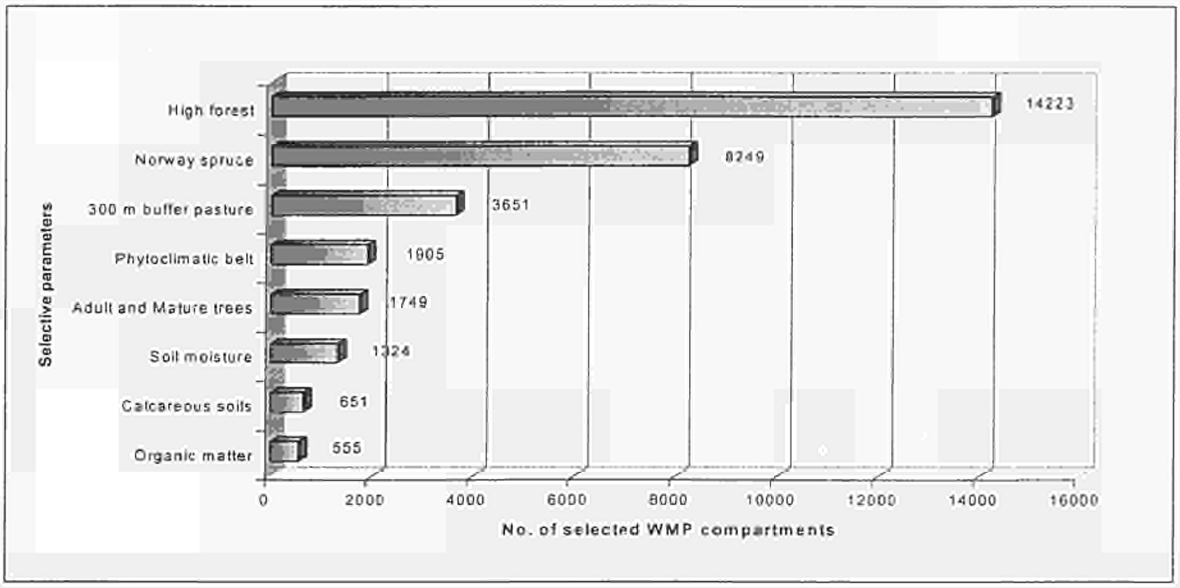

FIGURE 2 – Parameters used as filter to select the susceptible WMP compartments to annosum root and butt rots. These parameters were the following: presence of high forest, presence of Norway spruce higher than 95%, 300 m distance from pasture land, phytoclimatic belts outside *Picetum,* belonging to an adult or mature structure type, fresh and humid soil condition, calcareous soils and organic matter (Korhonen and Stenlid 1998). Progressive number of WMP compartments that are chosen during the selection process by each parameter.

It is interesting to note that the parameter Age do not decrease consistently the number of compartments. It was applied to selected the mature, adult and pole stage spruce stands that represent the majority and were the incidence is normally higher, and to avoid those few compartments with high proportion of spruce forest at seedling and thicket stages. An other interesting results was achieved when was applied the Phytoclimatic belt to filter all those Norway spruce compartments placed outside the Subalpine *Picea* belt (Schmid 1963). The reduction of compartment was about 48% (1905 out of 3651) when this parameter was used as filter. This is partially consequence of the forest policy during nineteen and the beginning of twenty century when Norway spruce was widely planted in *Fagus-Abies* woods as secondary *Picea* forest.
The last three parameters, moisture, limestone and organic matter content, are related to the soil conditions and are particularly important for the ecological requirements of such roots inhabitant pathogen. Is noteworthy to observe from the Fig. 1 that in the northwestern part of Trentino there is almost no presence of susceptible WMP compartments. These valleys, especially Fiemme and Fassa Valley, are historically considered to be the best sources of spruce timber in the Trentino province.
The geographical exposure of the selected 555 WMP compartments susceptible to annosum root rots is shown on Fig. 3. The preferred distribution of the susceptible compartments is obviously northwards and both Northwest and Northeast. This result is coherent with the ecological requirements of this fungus in the southern slopes of the Alps (Benyzry *et al.* 1988).
The elevation frequency distribution of the selected compartments is shown in Fig. 4. The average elevation is 1370 m and the higher frequency class is 1400-1500 m. The frequencies tend to decrease faster after 1500 m originating an asymmetrical distribution with a short right tail. This result is consistent with the natural distribution in elevation of Norway spruce and it is in agreement with previous reports that shown a similar trend of distribution (Tsanova 1974; Richter 1974). Moreover, a study carried out in Trentino on the incidence of *H. annosum* along 500 m of elevation, from about 1300 to 1800 m, shows a significant decreasing of the fungus attacks (unpublished data). In addiction, the same trend that occurs in mountain forests along elevation gradient can be seen along a latitudinal cline at the

northern limit of the fungus distribution (Korhonen and Piri 1994).

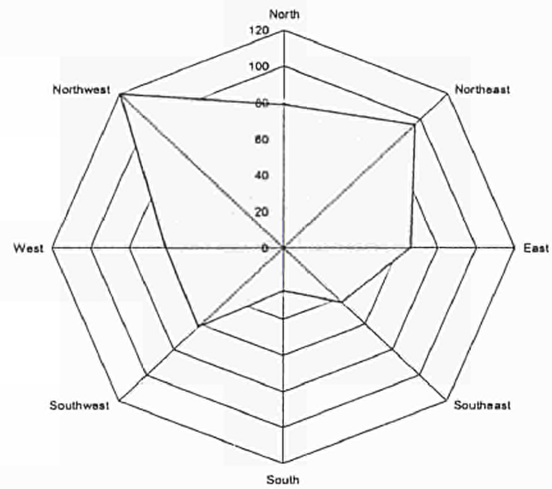

FIGURE 3. – Geographical exposure of the selected 555 WMP compartments susceptible to *H. annosum*

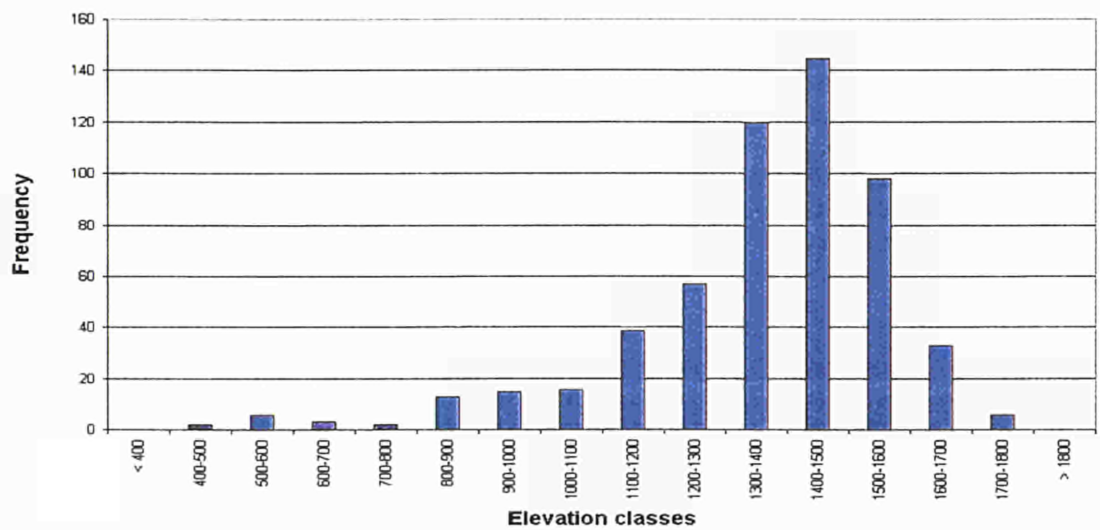

FIGURE 4. - Elevation frequency distribution of the 555 WMP compartments susceptible to *H. annosum*

4. Conclusions

Through the integration of *H. annosum* affecting factors with GIS models, new understanding of the root and butt rots susceptibility in a management area can be gained. As an important factor of a risk analysis the damage potential that arises from *H. annosum* infection can be estimated. Infection potential clearly depends by inciting factors such as former pasture land use, soil moisture, age of the wood, soil calcium content, phytoclimatic belt adequacy, organic matter etc. The model weighs the influence of any reached object on the point's damage potential based on the delay time and the damage susceptibility of the object. A susceptibility map for annosum root and butt rots arising from the point is then obtained by simply adding the weighted influences of all objects. This index could be further combined with the thinning and cutting historical data of the compartments and with the period when they were made to give a more complete image of the potential danger situation. Results revealed the potential for developing a decision support system based on *H. annosum* loss potential indices, although further validation of this field scale model at the WMP compartment level is needed.

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References

Anselmi, N. and Minerbi, S. 1989. Root rots involved in forest decline in Italy. *In* Proceedings of 7th International Conference on Root and Butt Rots of forest trees; pp.503-512. Edited by Morrison D.J. August 9-16 1988; Vernon and Victoria BC, Canada.

Benizry, E., Durrieu, G., Rouane , P. 1988. La pourrituredu coeur de l'épicéa, *Picea abies* (L.) Karst. *In* Auvergne. Etude écologique. Annales des Sciences Forestieres 45: 141-156.

Korhonen, K. 1978. Intersterility groups of *Heterobasidion annosum* (Juurikäävän risteytymissuhteet). Commun. Inst. For. Fenn., 94 (6): 1-25.

Korhonen, K. Piri, T. 1994. The main hosts and distribuition of S and P groups of *Heterobasidion annosum* in Finland. *In* Proceedings of 8th International Conference. *on Root and Butt Rots*; pp. 260-267. Edited by Johansson M. & Stenlid J. Wik, Sweden and Haikko, Finland. 9-16.08.1993.

Korhonen, K. Stenlid, J. 1998. Biology of *Heterobasidion annosum. In Heterobasidion annosum:* Biology Ecology Impact and Control, p.43-71.Edited by Woodward S., et al.. CAB International.

La Porta, N. 1999. Modelli di diffusione dei gruppi intersterili di *Heterobasidion annosum* in diversi soprassuoli forestali trentini. *In*: Proceedings 2nd Italian National Congress of Silviculture, (Ed. As srl) Venezia, 24-27th June 1998. Vol. IV, pp. 233-254.

PAT Vademecum 2001. Provincia Autonoma di Trento - Servizi Forestali. Vademecum 2001. http://www.provincia.tn.it

Richter, J. 1974. Die Ausbreitung der Rotfäule in der Fichte. Allgemeine Forstzeitschrift 29: 73-74.

Schmid, E. 1963. Die Erfassung der Vegetationseinheiten mit floristischen und epimorphologischen Analysen. Berichte der Schweizerischen Botanischen Gesellschaft. Band 73.

Shea, K.R. 1971. Disease and insect activity in relation to intensive culture in forests. *In*: Proceedings XV IUFRO Congress, Gainesville, Florida, USA, pp. 109-117.

Tsanova, P. 1974 The distribution of *Fomes annosus* and factors affecting its development in some natural Spruce forests. Gorskostopanska Nauka 11: 59-70; Bulgarian.

Arthropods abundance on the foliage of evergreen oak (*Quercus ilex*), deciduous oak (*Q. pubescens*) and Aleppo's pine (*Pinus halepensis*)

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ABSTRACT
A research was carried out on wooded areas of Santo Stefano di Quisquina and Bivona (Agrigento, Sicily) to estimate secondary productivity of two species of oaks, the first one evergreen (Quercus ilex), the second one deciduous (Q. pubescens), and one species of reafforested coniferous (Pinus halepensis), through the analysis of the arthropods living on their foliage. Two sampling methods were adopted: yellow water traps disposed on the branches of Q.pubescens and Q. ilex in the period November 1996-November 1997 (12 samples); and portable suction sampler used to collect arthropods on leaves of the three plant species from late April to October of the years 1997-99 (11 samples per year), collecting respectively 3133 and 11306 arthropods. Arthropods were collected more abundantly on Q. pubescens than on Q. ilex with both methods. Pine resulted the poorest habitat. Among taxa, Diptera resulted the most abundant in the yellow water traps, Coleoptera in the samples collected by suction sampler. Lepidoptera showed high differences among the two oak species, mostly due to the presence of larvae and adults of Tortrix viridana on Q. pubescens, probably due to the differences in the leaves turnover rate, which is complete in deciduous species, while it involves only 30% per year of the foliage in the evergreen one.

Keywords: Arthropods abundance, *Quercus ilex, Q. pubescens, Pinus halepensis*, Sicily

1. INTRODUCTION

Aims of this research were to estimate secondary productivity of two species of oaks, one evergreen (*Quercus ilex*), one deciduous (*Q. pubescens*), and one species of reafforested coniferous (*Pinus halepensis*), through the analysis of the arthropods living on their branches.

2. MATERIAL AND METHODS

The research was carried out on wooded areas of Santo Stefano di Quisquina and Bivona (Agrigento, Sicily). Woodplots where arthropods were sampled were characterized by the presence of *Quercus ilex, Q. pubescens* and *Pinus halepensis* as dominating arboreal species.

Two sampling methods were adopted: yellow water traps disposed within the foliage and portable suction sampler used to collect arthropods present on leaves. The traps were 25 cm in diameter and 5 cm deep, and contained water with a detergent to avoid insect escape from the trap. They were disposed on the foliage of five *Q.pubescens* and five *Q. ilex,* on a support fixed to the trunk. Twelve samples were collected in the period November 1996-November 1997; during each sampling period, the traps were active for 10 days.
The portable suction sampler was used to collect 11 samples per year in 1997, 1998 and 1999, from May to October; during each sampling session it was used for 20 minutes on the foliage of different individuals of each tree species.

3. Results and discussion

On the whole, 14,439 arthropods were collected, of which 3,133 in water traps and 11,306 using the portable suction sampler (Tab.1). The taxa most abundant were Diptera in water traps and Coleoptera in the samples collected by suction sampler.
Trend of arthropods (all taxa together) sampled by water traps within the foliage of evergreen and deciduous oaks (Fig.1) shows generally higher numbers in the evergreen oak, with the exception of May, when deciduous oak yielded more individuals than evergreen one. During the whole sampling period all

taxa were more abundant in *Q. pubescens* than in *Q. ilex*, with the only exception of Diptera, that were more abundant on *Q. ilex* from November '96 to April '97. Diptera were present in almost all samples with more than 50 individuals. All the other taxa were always scarcely recorded in all the samples, with a peak in May, in which higher numbers were collected in the deciduous oak than in the evergreen one.

TABLE 1 – Artropods collected on the three arboreal species

	Water traps		Portable suction sampler								
	1996-97		1997			1998			1999		
TAXA	*Q.p.*	*Q.i.*	*Q.p.*	*Q.i.*	*P.h.*	*Q.p.*	*Q.i.*	*P.h.*	*Q.p.*	*Q.i.*	*P.h.*
Dermaptera	0	0	88	39	9	60	46	18	62	41	15
Coleoptera	64	48	496	314	156	407	391	181	527	480	195
Lepidoptera	0	0	587	106	13	210	87	26	485	179	36
Hemiptera	0	0	251	192	95	265	183	224	268	279	147
Hymenoptera	228	152	232	91	59	164	89	46	294	239	103
Diptera	1,052	1,329	187	134	79	159	140	176	207	141	144
Orthoptera	0	0	37	15	0	31	31	0	14	14	0
Thysanoptera	83	52	14	0	0	13	0	0	14	0	0
Blattodea	0	0	0	18	0	0	9	0	0	14	0
Collembola	51	47	0	0	0	0	0	0	0	0	0
Araneae	17	11	144	133	130	135	162	131	153	120	132
N. TAXA	6	6	9	9	7	9	9	7	9	9	7
TOTAL	1,495	1,639	2,045	1,051	548	1,444	1,147	809	2,033	1,516	779

Abbreviations: *Q.p.* = *Quercus pubescens*; *Q.i.* = *Quercus ilex*; *P.h.* = *Pinus halepensis*

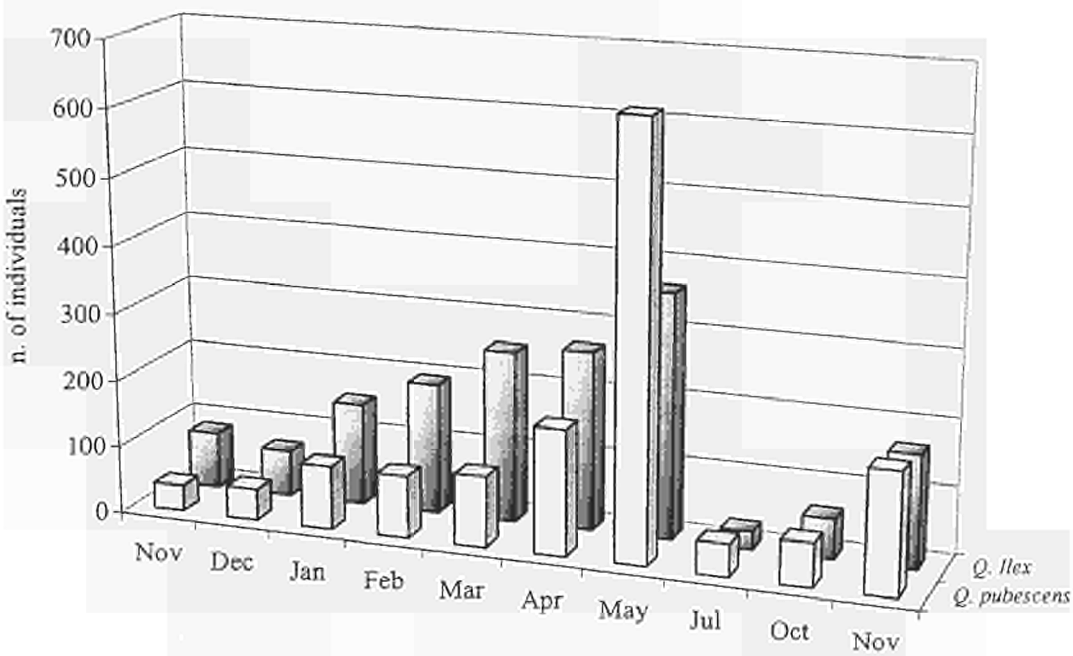

FIGURE 1 - trend of Arthropods collected on water traps

The arthropods collected by portable suction sampler were on the whole 5504 on *Q.pubescens*, 3687 on *Q.ilex* and 2115 on *P.halepensis*. Numbers were always more abundant within the foliage of oaks (both evergreen and deciduous) than within that of pine (Fig.2). From April to June deciduous oak yielded more individuals than evergreen one. Differences among habitats were significant (Wilcoxon test: evergreen/deciduous oaks, $T_{12}=0.0$, $p=0.002$; evergreen oak/pine, $T_{12}=5.0$, $p=0.008$; deciduous oak/pine, $T_{12}=0.0$, $p=0.002$).

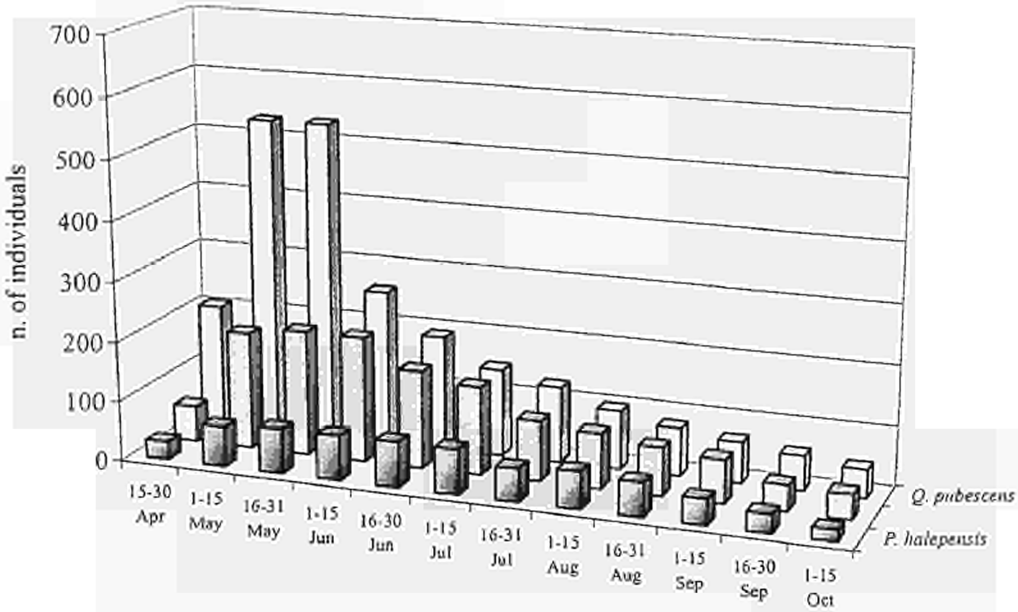

FIGURE 2 – Trend of Arthropods collected using the portable suction sampler.

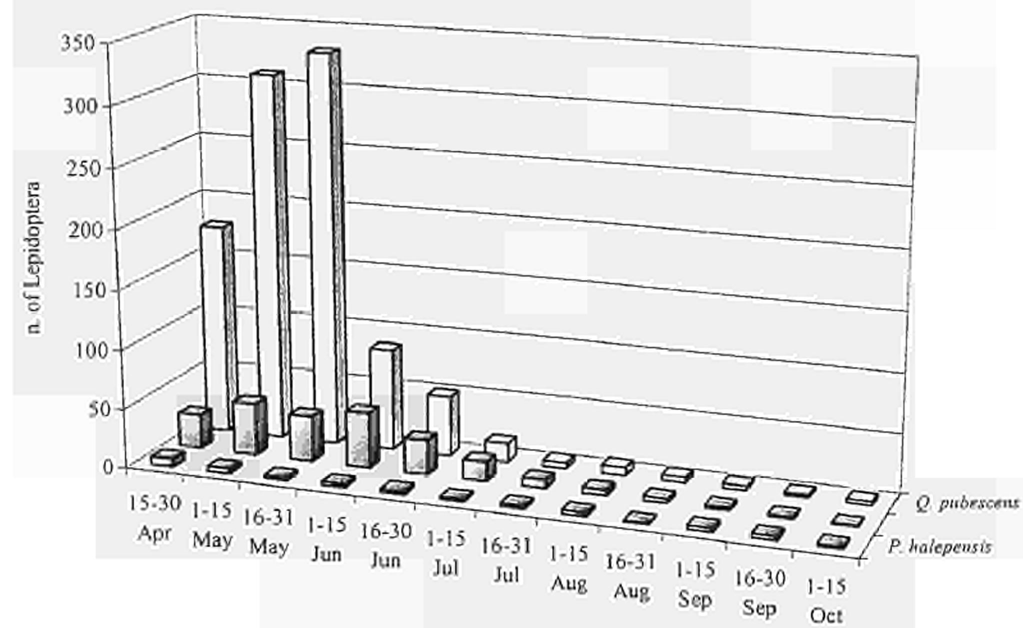

FIGURE 3 – Trend of Lepidoptera collected by portable suction sampler

Trend of taxa shows generally a gradient of richness, with maximum in the deciduous oak and minimum in the pine foliage. Nevertheless, Lepidoptera showed a great difference, with spring numbers significantly higher in deciduous oaks than in evergreen oak and pine foliage (Wilcoxon test: evergreen/deciduous oaks, T_{12}=6.50, p=0.01; evergreen oak/pine, T_{12}=7.0, p=0.01; deciduous oak/pine, T_{12}=1.5, p=0.005), mostly due to the presence of larvae and adults of *Tortrix viridana* on *Q.pubescens* (Fig. 3). This fact could be explained with the differences in the leaf turnover rate, which is complete in deciduous species, allowing to hold most abundant populations of leaf-eaters, while it involves only 30% per year of the foliage in the evergreen one. The lower abundance of caterpillars in the evergreen

oak is possibly related to the fact that leaves older than some months (c. 70% of the whole foliage) are no longer edible by most insects, because they are much too hard and contain tannins and other biochemical repellents (Feeny 1975; Lebreton 1982; Blondel and Dias 1994). In contrast, all the leaves produced in spring by deciduous are available for leaf-eaters, and hence there is much higher abundance of insects.
According to Blondel and Dias (1994) a relative environmental stability in the form of the seasonal constancy of the climate in Mediterranean ecosystems probably enhances arthropod diversity as compared with ecosystems in central Europe, which are characterized by a much stronger seasonality; therefore, a late production of a population-poor set of arthropods in evergreen habitats contrasts with a short highly productive occurrence of abundant species in deciduous habitats. Nevertheless, deciduous oak is a semi-deciduous species, which does not miss completely all the leaves. As matter of the fact, within many taxa sampled, only Lepidoptera (which at the larval instar are tipically leaf-eaters) resulted significantly more numerous in deciduous than in evergreen oak. As regards the species reafforested, Aleppo pine, their foliage resulted particularly poor of arthropods. As consequence of plant-animal interactions, also insect predators result scarcer in coniferous reafforestations than in broadleaved woods (Massa and Lo Valvo 1996).

REFERENCES

Arnold, A. J., Needham, P. H., Stevenson, J. H. 1973. A self-powered portable insect suction sampler and its use to assess the effects of azinphos methyl and endosulfan on blossom beetle populations on oil seed rape. Annals applied Biology 75: 229-233.

Blondel, J. and Dias, P.C. 1993. Summergreenness, evergreennes and life history variation in Mediterranean blue tits. In: Plant-animal interactions in Mediterranean type ecosystems, pp. 25-36. Edited by M. Arianoutsou and R. H. Groves, Kluwer: Amsterdam.

Eckerdt, F.E., Heim, G., Methy, M., Sauvezon, R. 1975. Interception de l'énergie rayonnante, échanges gazeux et croissance dans une foret méditerranéenne à feuillage persistant (*Quercetum ilicis*). Photosynthetica: 145-156.

Feeny, P.P. 1975. Biochemical coevolution between plants and their insect herbivores. In: Coevolution of plants and animals, pp. 3-19. edited by L.E. Gilbert and P.H. Raven, Univ. Texas Press, Texas,.

Floret, C., Golan, M.J., Le Floc'h, E., Leprince, F., Romane, F. 1989. In: Plant pheno-morphological studies in Mediterranean-type ecosystems, pp. 9-97. Edited by G. Orshan, Kluwer Academic Publ., Dordrecht,.

Lebreton, P. 1982. Tanins ou alcaloïdes: deux tactiques phytochimiques de dissuasion des herbivores. Rev. Ecol. (Terre et Vie), 36: 539-572.

Massa, B. and Lo Valvo, F. 1996. Arthropod abundance and breeding performance of Tits in deciduous, evergreen oakwoods and pine reafforestation of Sicily (Italy). Avocetta 20: 113-124.

SOIL QUALITY AND PEDOMESOFAUNA: A CASE STUDY IN SICILY

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Abstract

In a test area, in the inland of Sicily, a survey was carried out to evaluate the phenological differences in activity and diversity of the pedomesofauna of various soils under Eucalyptus sp.
In particular, were selected five sites located in the space with a differential GPS system. The mesofauna was surveyed, during the four seasons, both in the forest floor (O horizon), and in the first mineral horizon (A horizon) in five selected pedons. On the whole a total of 120 samples (60 organic and 60 mineral) were sampled.

All the soil samples were analyzed and some soil properties were studied in relation to the presence of pedomesofauna. Many thousands of invertebrates were detected, mainly arthropods, both in the organic and in the mineral horizons.

The more significant results pointed out that the pedomesofauna in winter prevails in the organic horizon and, in other seasons, is little more abundant in the mineral horizon of all selected pedons.

The more diffused species are Acari (26%) and Collembola (50%) which show a good relation with the contents of organic matter, clay and the CEC of the mineral horizons of the investigated soils.
In particular the number of individuals shows the highest value with a clay content of 400 g Kg^{-1}, with a organic matter amount of 28 g Kg^{-1} and with CEC values ranging between 33 and 36 $cmol_{(+)} Kg^{-1}$.
The high biodiversity observed confirms the good state of health of the ecosystem surveyed and the relationship between the pedomesofauna and the main physico-chemical parameters of the soils, suggesting to consider this kind of survey like a valid tool for monitoring forest soil quality.

Keywords: forest soils, soil mesofauna, biodiversity, monitoring soil quality, health ecosystem

1. INTRODUCTION

Although the pedofauna influences the processes of pedogenesis and has an important role in the main functional properties of the soil, it has rarely been used as a key-element in defining soil quality. As it has been stressed, this is due to the fact that the utility of pedofauna as a soil quality indicator is a function of the definition of soil quality which, in turn, depends on different functions, both biological and abiological, performed by the soil (Dazzi 2001). If we consider the biological functions of vegetal, animal and microbiotic activity, the usefulness of the pedofauna as a diagnostic element of soil quality, reaches its maximum, both in quality and in biodiversity. Previous work on soil fauna, dealt with the whole fauna both of litter and mineral horizons, and till now are rare the analyses on invertebrate communities in different horizons of a soil profile (Dazzi et al. 1998; Dazzi et al. 2000). The aim of this study is a) to consider the diversity and activity of some selected Orders of the mesofauna in some forest soils, in relation to the sampling period, the horizons of the soil surveyed, the selected tree species; b) to define the relation of the whole mesofauna with some selected parameters of soil quality and particularly the CEC and the organic matter content.

2. STUDY AREA

The study area is located in the inland of Sicily, Italy (FIGURE 1). The climate, from data recorded between 1951-1990 shows an average monthly temperature, that reaches a maximum of 25.7 °C in July and August, and a minimum of 8.2 °C in January and 8.7 °C in February. The average rainfall is 607 mm, with a maximum in December and January (91 and 81 mm respectively) and a minimum in June and July (8 and 10 mm respectively).

The udometric regime of the soil was defined "xeric", and the thermometric regime "thermic". The lithology (Dazzi and Monteleone 2001) is characterised by different substrata (Colluvial deposits, Clays with gypsum, Gypsum, Gypsarenites, Marly and/or sandy clays, Clays and marly clays, Alluvial deposits). According to Soil Taxonomy (USDA-NRCS 1999), soils were classified (Dazzi and Monteleone 2001) as Typic Haploxerert (pedon 3), Gypsic Calcixerept (pedon 64), Gypsic Vertic Haploxerept (pedon 22), Vertic Haploxerept (pedon 1), Typic Xerofluvent (pedon 2) (FIGURE 2). Land use is manly represented by woodland of *Eucalyptus* sp.

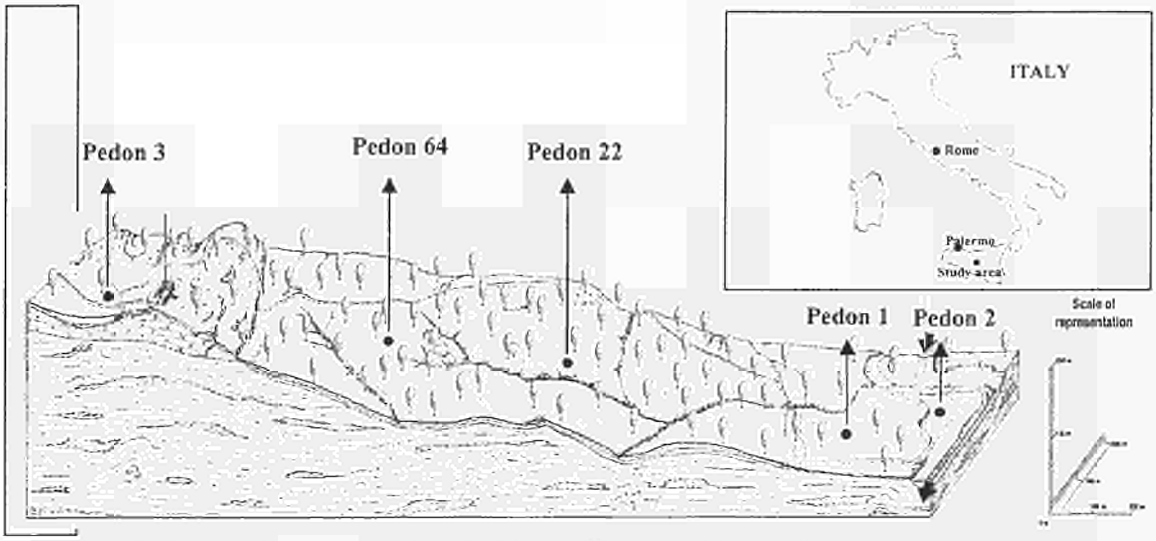

FIGURE 1 – The study area, made by a hillslope afforested with *Eucalyptus* sp., is located in central Sicily (Italy).

3. MATERIALS AND METHODS

The mesofauna activity was surveyed in the four seasons (December 1999, March, June and September 2000), both in the forest floor (O horizon) and in the first mineral horizon (A horizon) in five selected pedons under Eucaliptus (TABLE 1).

TABLE 1 - Main descriptive parameters of the selected pedons (according to USDA-NRCS, 1996).

Pedon n°	Site elevation (m a.s.l.)	Parent material	Landform	Slope (%)	Classification (USDA-NRCS, 1999)	Soil Horizons	Depth (cm)	Organic Matter (g Kg^{-1})	CEC (cmol$_{(+)}$ Kg^{-1})	Clay (g Kg^{-1})	B*	S*	C*	R*
3	478	Colluvial deposits	Dolina	4	Typic Haploxerert	Oi	0-2							
						A	2-10	30.3	45	575	C	3 f-m cr	h fr	2 f-m
						Ass1	10-30	29.3	42	595	C	3 m abk	vh fr	1 f-m
						Ass2	30-60	31	38	597	G	3 c pr	vh fr	1 f
						Ass3	60-120+	9.7	36	618		3 c pr	vh fr	1 f
64	320	Marly and/or sandy clays	Hillslope	4	Gypsic Calcixerept	Oi	0-2							
						A	2-14	33	36	497	C	3 vf-f cr	so fr	3 f-m
						Bk1	14-60	15.5	32	468	G	3 m abk	sh fr	2 f-m
						Bk2	60-80	11.4	25	626	G	3 m-c pr	h fr	1 f-m
						BCy	80-100+	15	24	562		ma	h fr	1 f
22	280	Clays and marly clays	Hillslope	15	Gypsic Vertic Haploxerept	Oi	0-2							
						A	2-20	18.9	27	611	A	3 f sbk	sh fr	2 f
						Bkss	20-50	15.3	20	691	C	2 m abk	h fr	1 m
						Byss	50-80	12.5	22	671	G	3 m-c pr	h fr	1 c
						C	80-110+	10.9	16			3 c pr-ma	vh fr	1 c
1	260	Marly and/or sandy clays	Terrace	2	Vertic Haploxerept	Oi	0-2							
						A	2-30	24	27	568	C	3 f-m cr	sh fr	2 f-m
						Bwss1	30-70	19	23	544	G	3 m-c pr	h fr	2 f-m
						Bwss2	70-125	14.3	23	419	G	3 c pr	h fr	1 f
						C	125+					ma	fr	1 f
2	255	Alluvial deposits	Terrace	2	Typic Xerofluvents	Oi	0-1							
						A	1-20	18.9	28	218	A	2 f sbk	so fr	2 f-m
						2A	20-30	20.2	24	425	C	3 m sbk	so fr	2 f-m
						3A	30-50	16.5	19	227	C	1 f sbk	so fr	2 f-m
						4A	50-100+	14.6	16	247		1 f abk	lo fr	2 f-m

*Abbreviations:
B (*Boundary*): A=abrupt; C=clear; G=gradual.
S (*Structure*): 1=weak; 2= moderate; 3=strong; ma=massive, vf=very fine; f=fine; m=medium; c=coarse; gr=granular; pr=prismatic; abk=angular blocky; sbk=subangular blocky
C (*Consistence*) *dry*: lo=loose; so=soft; sh=slightly hard; h=hard; vh=very hard. *Consistence moist*: lo=loose; vfr=very friable; fr=friable.
R (*Roots*): 1=few; 2=common; 3=many; vf=very fine; f=fine; m=medium; co=coarse.

Before sampling, each pedon was described in field, in hang-dug pits. In the opening of each pit particular care of some similarities, such as the distance from the trunk of the trees and the physical properties (light, exposition, pitch, etc.), was taken in order to overcome differences in soil characteristics due to phenomena such as the "steam flow".

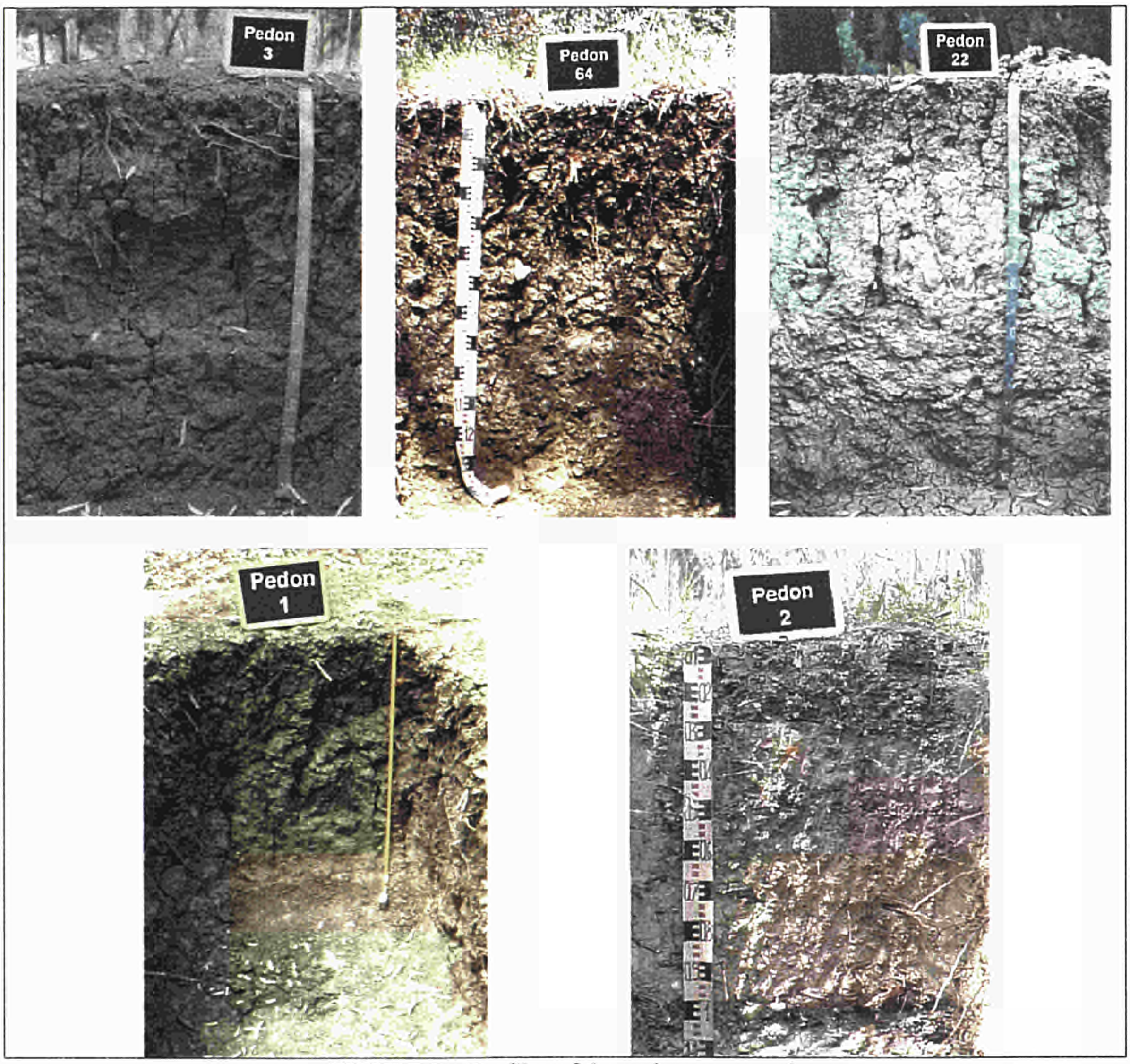

FIGURE 2 – Profiles of the pedons surveyed.

Samples of 500 cc were carefully taken using a square metal sampler, keeping the O and A horizons separate. Each sample was settled for one week in an extractor Tullgren Funnels type with 12 sets, where, due to 25 watt light, a temperature gradient is formed, which stimulates invertebrate movement toward the bottom of the funnel and than into an alcohol vial. The mesofauna extracted was identified to the Order or Class level.

4. RESULTS AND DISCUSSION

In the organic horizon the highest value of individuals was observed in winter, the lowest in summer (FIGURE 3a). The mineral horizon yielded a very poor pedofauna in winter, but good numbers in spring, followed by a fluctuating trend, that is a decrease in summer and an increase in autumn. Altogether, only in winter pedofauna resulted more abundant in the organic horizon than in the mineral one. Taxa more represented were Acari and Collembola (respectively 26% and 50% of the whole), which could be considered good soil bioindicators (Dazzi et al. 2000). Collembola (detritivorous organisms) showed maximum values in winter (mainly in the organic horizon) and minimum in summer (FIGURE 3b).

Acari (of which the detritivorous Oribatida were the most represented) peaked in spring (FIGURE 3c). However, both Acari and Collembola resulted very scarce in summer and showed an increase in autumn. Moreover, it is to outlined that the number of individuals shows a relation with the contents of organic matter, clay and the CEC of the mineral horizons of the investigated soils. In particular the total amount of pedomesofauna shows the highest value with a clay content of 400 g Kg^{-1}, with an organic matter content of 28 g Kg^{-1} and with a CEC ranging between 33 and 36 $cmol_{(-)}$ Kg^{-1}.

The high biodiversity observed confirms the state of health of these ecosystems and the relationship between the pedomesofauna and the main physico-chemical parameters of the soils, until now observed, suggesting to consider this kind of survey like a valid tool for monitoring forest soil quality.

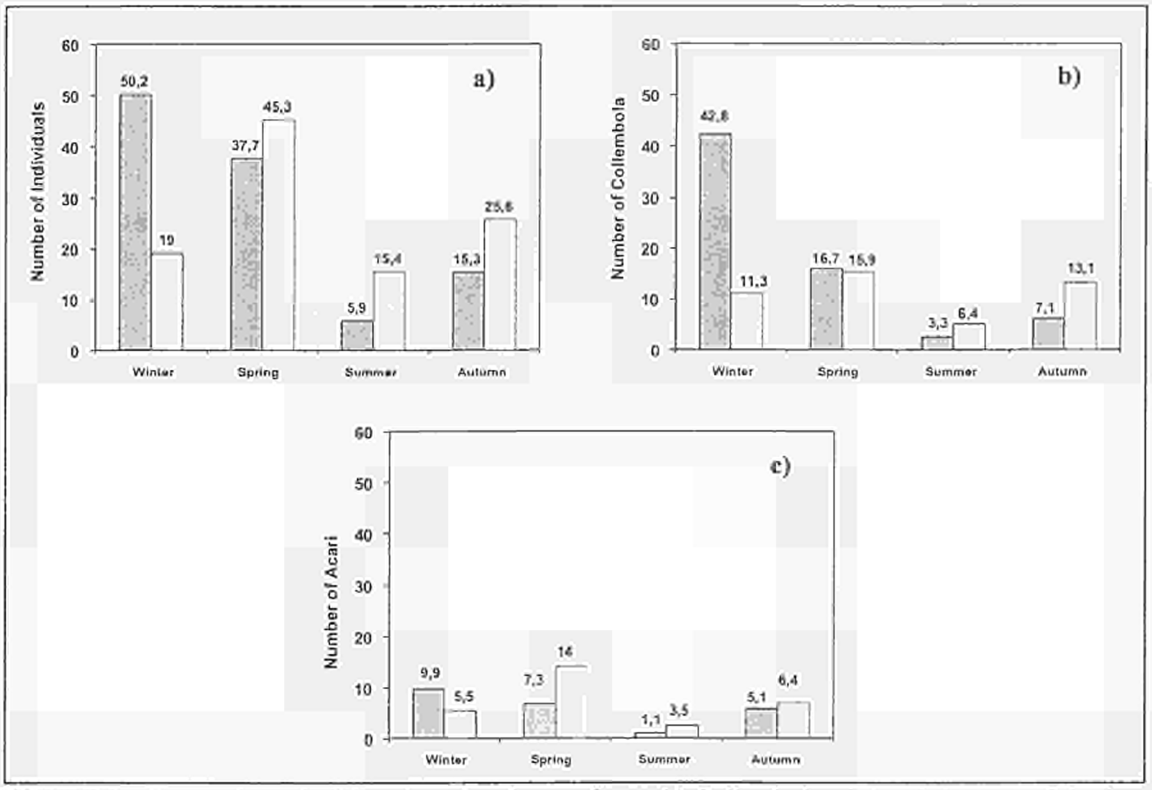

FIGURE 3 – Seasonal trend of the: a) total pedomesofauna; b) Collembola; c) Acari. (O horizon; A horizon).

REFERENCES

Dazzi, C. 2001. Salinità e Qualità del Suolo. Convegno Nazionale SISS: L'emergenza Suolo, Erice (in press).

Dazzi, C., La Mela Veca, D., Massa, B., Vacante, G. 1998. Una definizione della qualità dei suoli forestali in rapporto alla pedofauna. - Convegno Nazionale SISS "La Qualità del suolo per un ambiente sostenibile" Roma, 3-5 giugno 1997 Bollettino SISS n°3, anno XLVII, pp 381-392.

Dazzi, C., Massa, B., La Mela Veca, D.,Vacante, G. 2000. Pedo-mesofauna activity as soil quality indicator in a forest Mollisol. Proceedings of the ESSC Int. Congress: Men and Soils in the Third Millennium. Valencia.

Dazzi, C., Monteleone, S. 2001. Soils and soil-landform relationships along an elevational transect in a gypsiferous hilly area in central Sicily, Italy. 7th Int. Meeting of Soils with Mediterranean type of Climate. Valenzano, Bari. (in press).

USDA-NRCS 1996. Soil Survey Laboratory Methods Manual. Soil Survey Inv. Rep. N.42, vers. 3.0 USDA, Washington D.C.

USDA-NRCS 1999. Soil Taxonomy, a basic system of soil classification for making and interpreting soil surveys. 2nd ed. Agriculture handbook N°436, Washington D.C.

CORK OAK DISTRIBUTION IN SARDINIA: INTEGRATION OF GIS AND EMPIRICAL MODELS

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ABSTRACT

The aim of this paper is to demonstrate the integration of GIS and empirical modeling approach for cork oak suitability mapping and cork quality prediction. Empirical models relate environmental parameters such as slope, aspect, soil type and rainfall to suitability for the production of different cork qualities. GIS functions process maps and remote sensing data, including aerial photography, estimating cork oak potential distribution and production. Considering three test areas, suitability estimates will be evaluated with reference to actual productivity and to the potential for cork oak cultivation expansion. Validated results will be extended to identify potential areas for new oak cork production. The work suggests applying this methodological approach to develop an inventory of actual and potential cork production sites, as objective basis for regional development planning and management. The study demonstrates that integrating GIS and modeling approach enhances evaluation ability and the usability potential resulting products. Any environmental factors can be jointly analyzed both visually and by quantitative means, moreover, once the system is correctly integrated in the organization, updating and development of the new products implies relatively limited investments.

KEYWORDS: GIS, SUITABILITY MAPS, CORK OAK

1. Introduction

It is well know that in Mediterranean climatic conditions, the quality of cork is related to those ecological factors, elaborated from the available thematic cartography. Through the present study has been shown, by means of GIS tools, the potential areas for cork oak, through a map at the scale of 250.000. The maps is the result of an empirical model, whose inputs are parameters such as rainfall, temperature, aridity index, aspect, index of Pavari and soil type. Different references and the results of field survey, in three test areas, help to fits the right value for each map's features and the output map is the synthesis of the considered maps values.

2. Methodology

The geoinformation is the input of the Geographical Information System and the right combinations of these synthesized information allow to get as a final result, a map of Land Suitability for the cork oak and cork quality map.

Starting from the data obtained by the field survey on three test area of Sardinia and taken into account the environmental processes involved in the phenology of the cork oak, empirical considerations are go over to figure out the relationship between cork's quality and environmental parameters. The procedure of the study is based on merging the following data:

- an aridity index, based on UNEP aridity index I=P/ETP, where P = average of years rainfall, ETP = potential evapotranspiration calculated by Hargraves, 1951-1980, where the index classifies the climatic area as arid (<0.5), sub-wet (0.5-0.65) and wet (>0.65); considering the phenology of the cork oak a fit evaluation based on suitability approach has been done. FIGURE 1
- Pavari's index (classification based on *Lauretum*, warm, medium warm and cold and *Castanetum*) The cork oak is well grown in a *Lauretum* warm, but the quality of cork is best in *Lauretum* cold; considering the phenology of the cork oak a fit evaluation based on suitability approach has been done. FIGURE 2
- Average rainfall, the first climatic variable. It is well know that the best rainfall is almost 600 mm. A fit evaluation based on suitability approach has been done, to get a right value for this map. FIGURE 3

- Average temperature, the second climatic variable among with 1960-1990 years. The best temperature is figure out 14-15 degree. . A fit evaluation based on suitability approach has been done, to get a right value for this map. FIGURE 4
- Soil type: alchaline soils aren't fit for the cork oak. The same procedure has been followed to get a right value of suitability map. FIGURE 5
- The aspect influences the oak and the north aspect is rather fit. FIGURE 6

3. Result

The set of maps, elaborated by the means of GIS tools, are present here. The final result of this elaboration is the Land Suitability for Cork Oak and Cork Quality. The legend show the suitability of the natural resources, based on the ecological consideration of the cork oak. This legend present not only the land suitability but also a grade of quality of cork. Moreover the potential map is strictly related to an ecological factors that influences deeply the quality of cork. It is opportune read the map in integrated way. FIGURE 7

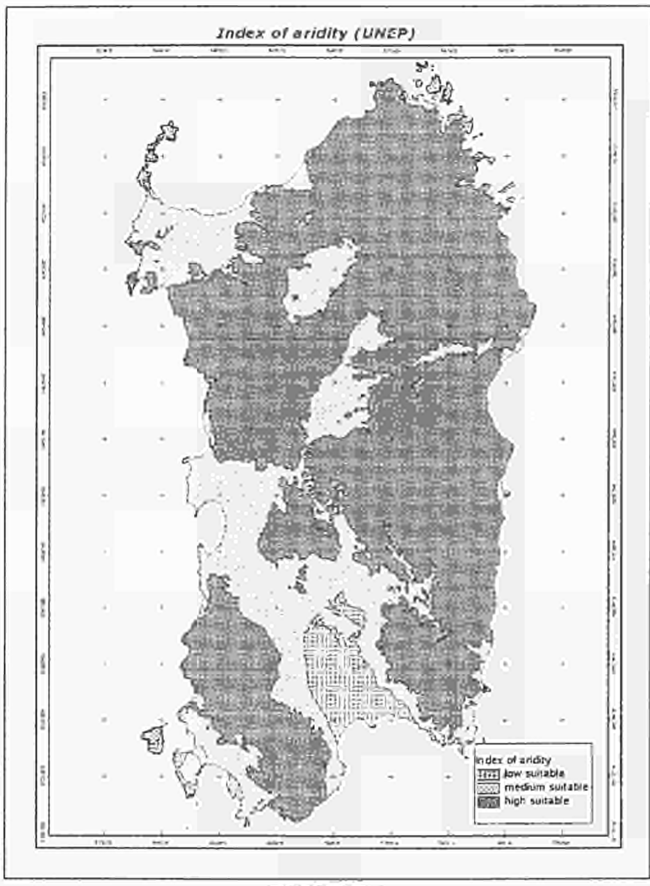

FIGURE 1

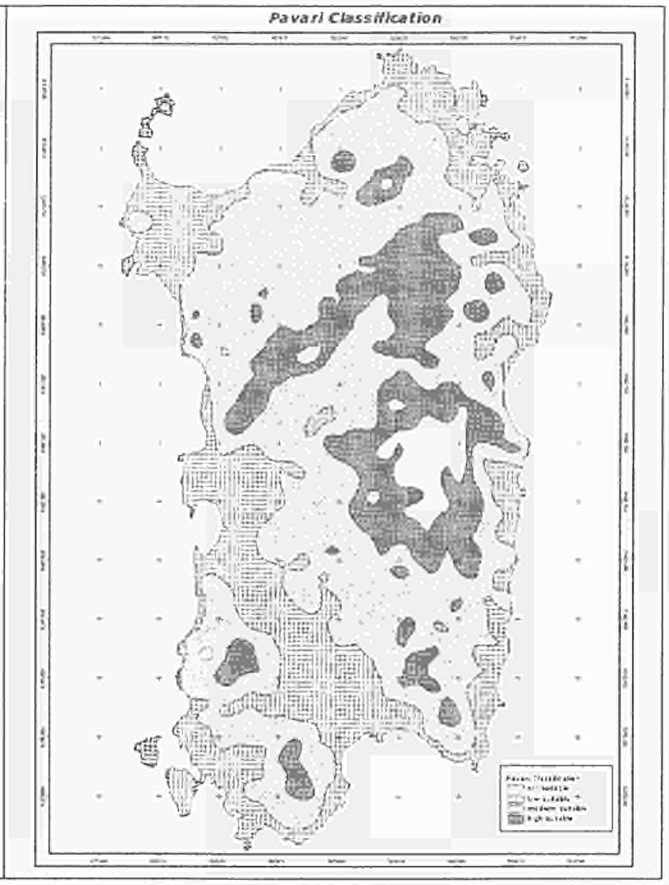

FIGURE 2

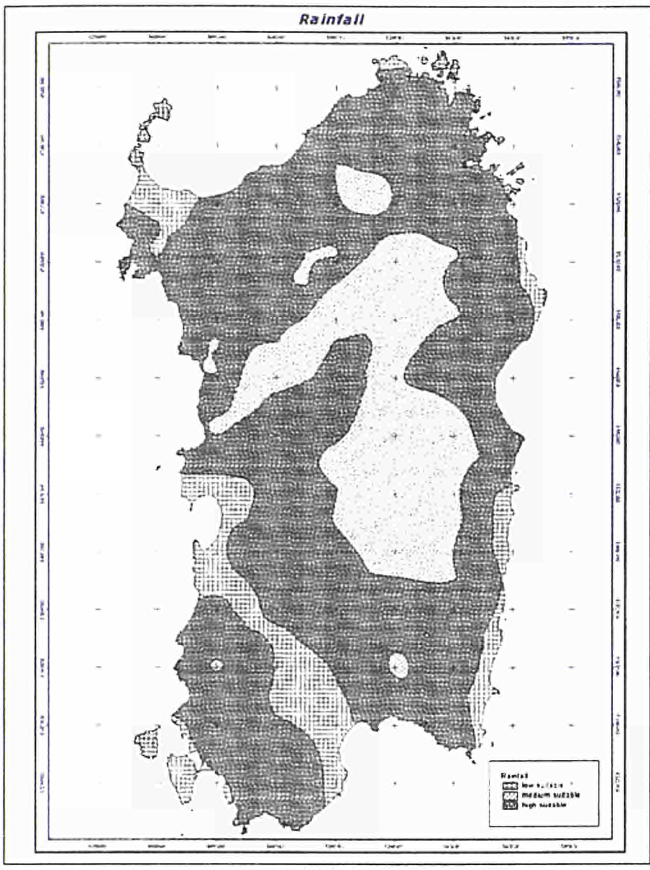

FIGURE 3

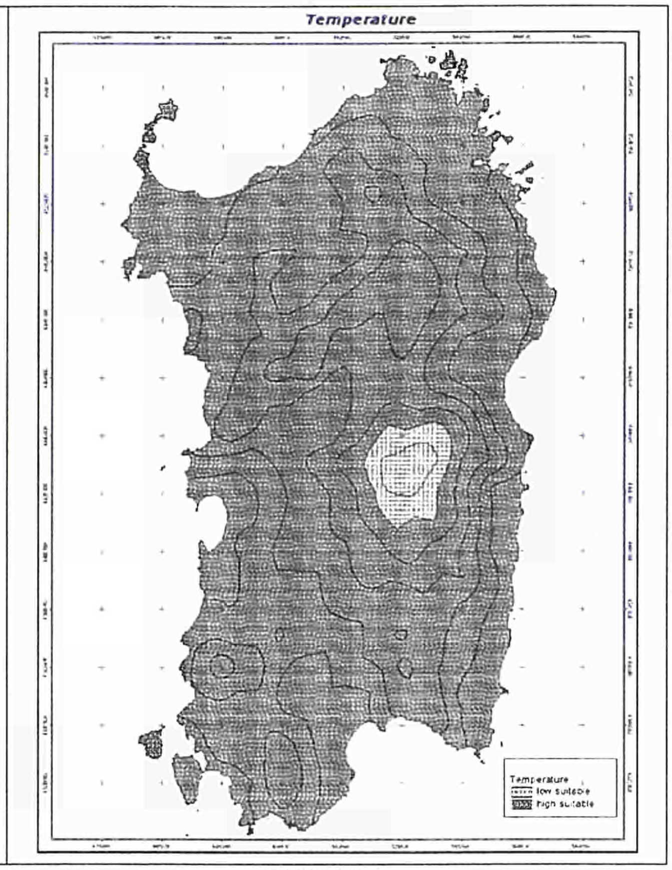

FIGURE 4

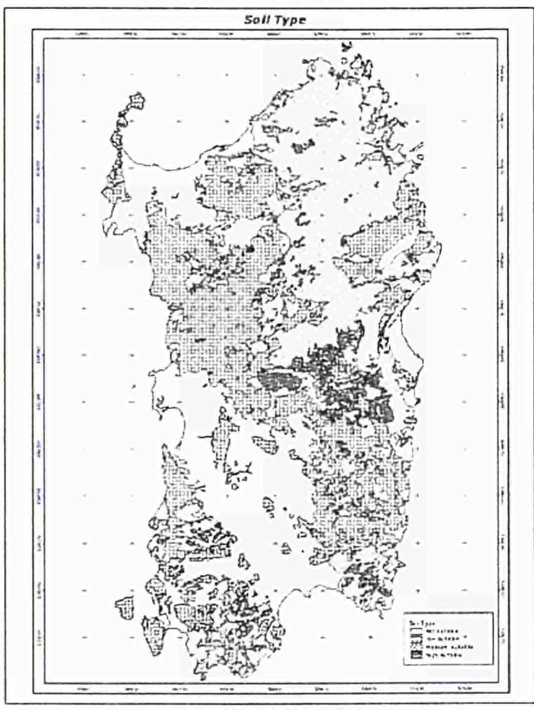

FIGURE 5

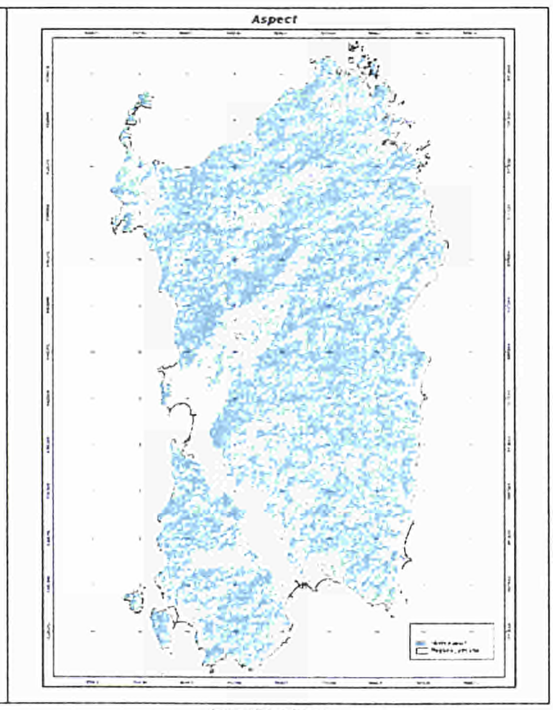

FIGURE 6

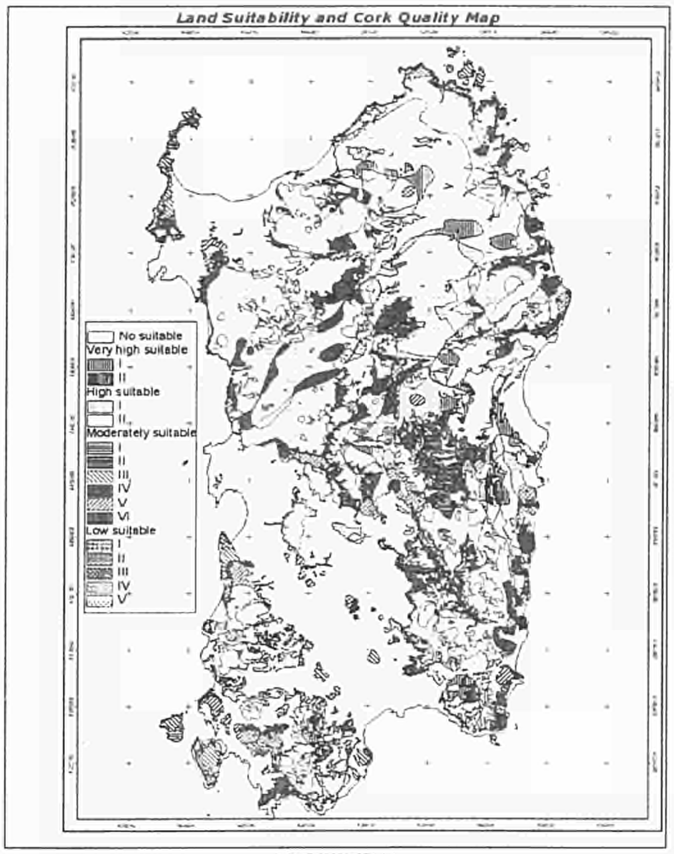

FIGURE 7

References

J.R. Gonzales Adrados, R. Elena Rossellò et al. 1992. Potencialidad del territorio para el alcornoque en extremadura. InScientia gerundensis, 18 pp.185-194. Edited by Univeritat de Girona.

Interpretation of ETM$^+$ data for natural and semi-natural areas of Sardinia Italy

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ABSTRACT

The map of natural and semi-natural vegetation areas of Sardinia represents an important tool for the knowledge on the vegetation cover of the island. The results produced by this study integrate and complete the already existing cartography, assuming great importance by defining, from qualitative point of view the exact (geographically correct) distribution of forests in the region.
However, this elaboration does not define thematic information of different vegetation classes, but identifies and highlights variations in density and structure of green coverage.

This cartographic instrument has been realised by the Photogeology and Remote Sensing Laboratory of the University of Cagliari within the Research Project "Digital Information of the Forest Map of Sardinia", a study contract with the "Stazione Sperimentale del Sughero" of Tempio Pausania - Regione Sardegna – and CINSA consortium.

KEYWORDS: FOREST MAPPING

1. Introduction

The map of natural and semi-natural vegetation of Sardinia has been realized by the Photogeology and Remote Sensing Laboratory TeleGis of the University of Cagliari - Earth Science Department. - within the research project "Digital Information of the forest map of Sardinia" sponsored by the "Stazione Sperimentale del Sughero - RAS" in Tempio Pausania (SS), North Sardinia.
The aim of this project is the realization of a geographic database to manage the already existing cartography of the forest area for the RAS and specifically to transfer in digital format 'the forest map of Sardinia', printed on paper in 1988, using as base cartography the IGMI maps in scale 1: 25.000.

The necessity to update the information of this thematic instrument leds to the realization of a new survey, using the1999/2000 Landsat 7, in a GIS environment.
The interpretation of images of the whole Sardinia has been realized with the use of an original legend, studied in cooperation with the technicians of "Stazione Sperimentale del Sughero". This legend has been optimised to classify satellite images and furthermore it has been effective as a descriptive synthesis of the Forest Map of Sardinia articulated legend.

2. Material and method

The work has been carried out using images obtained by Landsat on the 11 of November 1999 and 18 of December 1999, on orbits 192 and 193, scene 032 and 033, which covered the island territory.
Wintertime was chosen to analyze the self-sown vegetation, especially the woody one, in the particular phenological time of the deciduous species.
The minor quantity of biomass observed during this season, compared to the evergreen floristic associations, permitted discrimination within the different associations; this has to be considered a further value compared to the cartographic data, supplied from the EU Project "Corine Land Cover".
The execution phases of the project are synthetically reported in the scheme below (Tab. 1).
The problems encountered during the satellite data operations are especially linked to the supervised classification by photo-interpretation technique. This technique was chosen in order to promote the superimposition control of ancillary data inserted in the GIS as well as to exploit the contribution of photo interpreters, for their specific area knowledge, during the execution of the work.
The datasets used were surveyed by satellite with a temporal difference phase of one month, between east and west sector, as cloudy coverage did not allow clear shots upon two consecutive satellite orbits.
The two passages were gained, both over land and through the atmosphere, on very different humidity conditions; in fact the first passage was just before the dry season and the second was in the middle of the

rainy season.

TABLE 1. The table reports the execution phases of the project.

PREPROCESSING OF THE SATELLITE DATA	• Georeferencing on the Italian Coordinate System of Gauss-Boaga (GCP method). • Analysis of data set information • Creation of a false color composite on RGB 4,5,2
Legend formulation	• Comparative study between Corine Land Cover legend and Forest Map of Sardinia legend • Definition of the synthesis elements
Interpretation / Conversion to Vector Format	• Study of interpretation keys • Definition of mappable minimum unit • Interpretation and digitizing
Realization of associated Database	• Predisposition • Implementation of Database.

To minimize the great differences between data information, the images have been geometrically corrected on UTM projection system 32-north zone Datum WGS-84 on 1:25.000 scale, and with a radiometric enhancements for a georeferenced multiband composition in a RGB mosaic, saved in GEOTIFF format.
More then 400 points were located on regional territory with a margin of error less then a pixel size; with a polynomial transformation of 1^{st} order the dataset has been reclassified with the nearest neighbour method.
The geometric correction of the images, tested with coastline superimposition, digitalized on 1:25.000 topography, was completely satisfactory.

3. Legend

The studied legend (Tab. 3) comes from the revalidation of "Carta Forestale della Sardegna"; adapted in order to read the green coverage trough the discrimination criteria on the multispectral satellite images, which are linked to the items of Corine Land Cover Project, also derived from interpretation of satellite data.
The comparative study of legend had the aim to connect all informative contents of the two maps; which were realized with completely different modalities.
The "Carta Forestale della Sardegna" is the result of a land surveying that emphasizes the knowledge of the quality and the quantity of the forest resources in the region. The legend is not determined deductively, but it varies each time according to the specified necessity of representation.
The legend definition parameters are valued not only through taxonomical parameters but also through ecological and socio-economic components.
The "Carta della copertura del suolo della Sardegna" (Corine Land Cover Map) shows geographical distribution of natural and anthropogenic areas by reading satellite images on filtered 432 RGB color composit.
The project legend is deductively defined: each cover class has been recognized on the Island through a diligent examination of the satellite images interpretation keys, also helped by photo interpretation.

Without underestimating the great differences between the two legends, some common elements which illustrate a close connection between the two maps have been recognized; both in fact, consider green species which make up the associations and also the purity, the covering density, the damage caused by human activities, such as fire or grazing. The utilized legend is based upon these common parameters.
On the whole nine cover classes have been defined, joining under the same category both anthropogenic and natural coverage. For each class a spectral reading key has been codified upon satellite image to define classical parameters: outline sharpness, color and tone, texture and structure; this kind of description ensures homogeneity and objectivity of the interpretation.

TABLE 2. The Land Cover legend used to discriminate classes with different forestry interesting.

Areas with a high forestry interest	Bs	Evergreens wood: Surfaces more or less covered with evergreen arboreal woody species with a covering density value above 40 % Ilex wood and corkwood variously cut (coppice, standard selected coppice, high-forest) with or without the presence of undergrowth, pure or mixed up with subordinate elements of deciduous leaves arboreal woody species: (Oakwood, Chestnut wood, Hazelwood).
	Bc	Deciduous wood: Forested surfaces, pure or mixed, more or less covered with deciduous arboreal wood species, with a covering density value above 40 %. Oakwood, Chestnut wood and Hazelwood variously cut (Coppice, Standard selected Coppice, High Forest) with or without undergrowth pure or mixed with a few elements of Ilex wood and Corkwood
	CB	Mixed wood: Mixed wood of conifers and broadleaved, with important autochthonous formations
Areas with a potential forestry interest	Mf	Forested bush: Forest zone more or less degraded, with a positive or negative developing trend. It includes Ilex wood and/or Corkwood, with a quite important presence of Oleaster and Locust-tree that often prevail. Areas of highly bushed and with an easy forest recovery are also included.
	Sa	Rural forested surfaces - open forest surfaces: They include areas with Ilex wood, Corkwood and/or Oakwood with a covering density below 40%, pure or mixed, variously managed and also areas with a few arboreal elements
	C	Conifers wood: Artificial conifers plantations, situated in continental area or in coastline area upon a rocky substratum. It includes coverage with or without renovation. Lack of autochthonus elements, possible presence of bush elements.
	Cr	Artificial planting of young conifers, deserted or not well grown.
Areas without forestry interest	A	Antropogenic and natural surfaces Without forest interest: Urbanized Areas Degraded zones with scarce or absent green coverage Rural zones of any kind (sown and orchards) Rocky grounds Littoral bushes Exotic species on a bare soil Bared and bushed grazing areas Humid areas
	I	Burnt areas

4. Classifications and Vector Conversion

The stage of classification was realized in a GIS environment using MapInfo, 5,0 for the Georeferencing

of raster image and interpretation on the monitor.
The closed polygon, produced in vector format along the borders of the discriminated classes, were contextually connected to a linked database.
The map scale is 1:50.000, and the interpretation was made setting the zoom of the image always below 40.000, to obtain the right details in digitizing.
The mappable minimum unit is represented from a real surface of 9 ha, corresponding to a square with 6 mm side on the 1: 50.000 map.
Classification activity has been many times hindered by the presence of large and evident shadows on the satellite data, for the lowest inclination angle of sunrays during winter season. These shadows sometimes have completely hidden the image information, or have made very hard to recognize and classify different covers.

5. Results

The knowledge of physical and biological reality is, as already know, an important element to define the planning and the rational management of the area territory. The land coverage thematic value is, anyway, an important data, quite useful to quantify, and it is also an indirect indicator of environment health.
Numerical cartography produced within this Research Project enriches the already existing information on regional forest patrimony and offers an upgrade of the geographical data, reliable under geometric outline, about the real extension of the forested areas in Sardinia.
Some of the first quantity valuation extracted from the data base are shown in the Tab. 3.

TABLE 3. The table shows the areal distribution of different land cover classes.

Classes	Areas	Total Sur. Km2
I	7	16,80
Bs	1134	2642,97
Bc	32	110,04
CB	67	221,70
Mf	921	1246,3
Sa	521	1698,98
C	277	480,30
Cr	85	248,09
Total	*3048*	*6665,18*

The limit of the information of this map is the exclusion of all those surfaces which were too small to be represented at the adopted scale; these areas, considered all together, could represent important units.
On the other hand, these part of territory could be counterbalanced from small surfaces which are inside a larger mapped area, but unrelated to it.
By difference between the regional surface (24.084 Km2), the area which is not of forestry interest reach a total of 17.399 Km2. In this category are included simple bush and degraded bush (by Corine we know only the surfaces value).
If these territories do not suffer of great anthropogenic charge, there are some possibilities to improve the green cover, both in quality and quantity and to use it as a part of forestry economy.

6. Conclusions

On the map of natural and semi-natural vegetation areas of Sardinia, all the green cover that can be utilized for forestry have been mapped and classified.
This study highlights density variations of green formations and their structure, apart from the shrubs and herbaceous plants.
The result achieved in this study represents on the forest study in Sardinia an important instrument of knowledge which spots a '*status quo* ' of the forested environment and it is useful to be referred to in case of alteration and man interference.
Moreover this work can be utilized as a tool instrument in multi-temporal analysis in order to monitor the developing dynamics of the area.

References

Biggio, G., Careddu, M.B., Crobu, D., Marceddu, L., Marini, A., Melis, M.T. (1996). Carta della copertura del suolo della Sardegna, pp. 209 – 217. Atti del 1° Convegno di Telerilevamento e Cartografia tematica, Cagliari 13 – 15 novembre 1996, Rendiconti del Seminario della Facoltà di Scienze dell'Università di Cagliari (Suppl. vol. LXVII, 1977)

Cabrai, F., Careddu, M.B., Marini, A., Melis, M.T., Mura, M., Pintus, C. (1998). The use of satellite remote sensing data for the interpretation of landscape components, pp.313 – 318. Proceedings of the International Seminar "Indicators for assessing Desertification in the Mediterranean", held in Porto Torres, Italy 18 – 20 September 1998.

Study of land cover change of Karnali region (Western Nepal) by remote rensing

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Abstract

The aim of this work is to evaluate the forest cover change and the soil degradation during the past 23 years of Jumla Mugu and Kalikot districts, all belonging to Karnali region in the High Himalaya, Western Nepal, using remote sensing techniques. Surveys and fieldwork were carried out by two expeditions: JUMLA FOREST '94 and RARA SAIPAL'99, organised by Tuscia University, Viterbo, Italy. Two sets of satellite imagery were classified (supervised classification) and compared to determine the extent, spatial distribution and recent change of the forest types detected: Landsat ETM+ scene acquired on October 3, 2000, and Landsat MSS scene acquired on March 23, 1977. The annual rates of deforestation and soil degradation have also been calculated in order to evaluate the intensity of human pressure upon the area.

Keywords: Nepal, Karnali, Rara, Remote sensing, Land Cover Change

1. Introduction

The case study provides information about the forest cover state and change between 1977 and 2000 of Jumla Mugu and Kalikot districts, all belonging to Karnali region in the High Himalaya, Western Nepal, using satellite images (Figure 1). The smallest Nepalese Park, the Rara National Park, lies in this area.

FIGURE 1

In the past 50 years Nepal has seen a drastic decreasing of its natural forests. At the moment Nepal has around 35% forest cover, although at least a quarter of the forest area is heavily degraded (FAO 1999). Tree resources are of vital economic importance for such a poor Country. Rural people gather fuel and fodder, graze livestock, hunt game, collect fruits, building materials, medicines and herbs, and use their local woodland resources to satisfy many other basic needs.

The Karnali region is the remotest and poorest region of Nepal. The forests in this area are heavily under human pressure. Studies on vegetation and phytogeography of Karnali region had shown that this region has many indigenous features to merit a distinct ecological entity in Nepal, therefore the area needs a particular monitoring and protection. This study focuses on the effect of the human pressure during the past 23 years and on the benefits of the park. Although the region lies within the subtropical monsoon climatic region, the wide range of topographic conditions (altitudinal range 6883-1400 m) allows for a wide variety of forest types. The distribution of natural forest generally follows altitudinal zones.

The Ecological zones and their vegetation present in the area are showed in the Table 1 (Shrestha T.B. 1985).

2. Methods

Surveys and field work were carried out by two expeditions: JUMLA FOREST '94 and RARA SAIPAL'99, organised by the Department of Forest Environment and Resources of Tuscia University, Viterbo, Italy. Site characteristics and vegetation data were sampled during the trekking, using GPS technology and former-USSR military cartography, the largest scale topographic map available of the area (1:200000).

TABLE 1

ALTITUDITUDE (m)	ECOLOGICAL LEVELS	TYPES OF VEGETATION
1200-2100	Subtropical level	*Pinus roxiburghii, Quercus incana, Q. lanuginosa*
2100-3000	Temperate level	*Pinus wallichiana, Picea smithiana, Cedrus deodara,* Decideous mixed forest *(Aesculus-Juglands Acer)*
3000-3700	Subalpine level	*Betula utilis, Abies spectabilis, Quercus semicarpifolia* (BAQ), *Rhododendron spp.*
>3700	Alpine level	Alpine meadow

Two sets of satellite imagery, acquired approximately twenty years apart were classified and compared to determine the extent, spatial distribution and recent change of the forest types detected. The remote sensing based datasets includes: LANDSAT ETM+ eight-band scene acquired on October 3, 2000, and Landsat MSS four band scene acquired on March 23, 1977. All datastets were georeferenced, classified (supervised classification) and compared. A detailed Land Cover Map has been carried out to analyse the forest cover of the area at the present time, by classifying ETM+ scene of the study area with a spatial resolution of 30x30m.

In order to analyse the changes occurred in the 23 year period (1977-2000) two maps were carried out from Landsat ETM+ and MSS scenes with the same coarse spatial resolution of the MSS (80X80m), and the same classes. These two maps have been compared and the annual rate of cover change (referred to 1977) was calculated.

Normalised Vegetation Index (NDVI) for both the images' sets was also calculated, and soilmasks of the two scenes have been carried out considering only all the pixels with NDVI values below zero (no vegetation).

A detailed Land Cover Change Map was built about the Park area, with its buffer zones included to analyse the spatial distribution of the changes occurred in the 23 year period. Furthermore Kappa Index of Agreement (KIA) has been calculated for the Landsat ETM+ classification in order to evaluate the classification accuracy of the detailed land cover map.

3. Results

The detailed classification of the Landsat ETM+ scene shows that at the moment the area (2565 km^2) has 42% of forest cover. The extent and rate of the features classified in the map are represented in Table 2. The classification has a quite good accuracy level (KIA= 0.77), considering all the classification problems that arise due to the land geomorphology.

The comparison of the classified 2000 Landsat ETM+ (spatial resolution degraded into 80x80m), with the classification derived from the 1977 Landsat MSS data, showed that the area had lost 4 per cent of its forest cover over 23 year period, the equivalent of 0.5 per cent per annum (Table 3, 4). If the area of the Park is excluded, the rate equals 0.6% of annual deforestation.

More concern arises considering all the meadows and the agricultural areas observed in 1977, which by 2000 turned into bare soil. The annual rate of such soil degradation is 6.2 per cent. In Figure 2 and 3 are represented the two soilmasks in which only the areas without soil are indicated. On the other hand the Park area (106 km^2) shows opposite trends. Over 23 years the forest cover increased of 6 per cent of forested area observed in 1977. The annual rate of forest growing is 0.5 per cent.

TABLE 2

Detailed Land Cover Map 2000-ETM+ (30x30m)		
Class	Ha	%
Water	984.	0.4
Rocks	74730.	26.6
Meadows	30997	11.0
Agricultural land-Karnali	12609	4.5
Agricultural land-Jumla	9378.	3.3
Pinus wallichiana+Picea smithiana	39159	13.9
Decideous Mixed Forest	19304	6.9
BAQ	35724	12.7
Quercus semicarpefolia	21566	7.7
Alpine meadows	25138	9.0
Snow	6867	2.4
Clouds	4386	1.6
Tot	280848	100

TABLE 3

1977 - MSS		
Class	ha	%
Water	993	0,4
Rocks	31245	12,0
Meadows	114060	43,7
Temperate level forest	36089	13,8
BAQ	74885	28,7
Clouds	0	0,0
Snow	3902	1,5
Total	261174	100

TABLE 4

2000-ETM+		
Class	ha	%
Water	1007	0,4
Rocks	75908	29,1
Meadows	63587	24,3
Alpine Meadows	15158	5,8
Temperate level forest	31049	11,9
BAQ	66280	25,4
Clouds	2236	0,9
Snow	5949	2,3
Total	261174	100

TABLE 5. Forest cover change and annual rate in the 23 year period					
	1977		2000		Mean annual rate (%)
	Forest Cover (Ha)	%	Forest Cover (Ha)	%	
The whole study area	110974	42	97329	37	-0.5
Without the Park area	104871	42	90591	36	-0.6
Only the Park area	6103	54	6737	60	+0.5

Soilmask MSS-1977

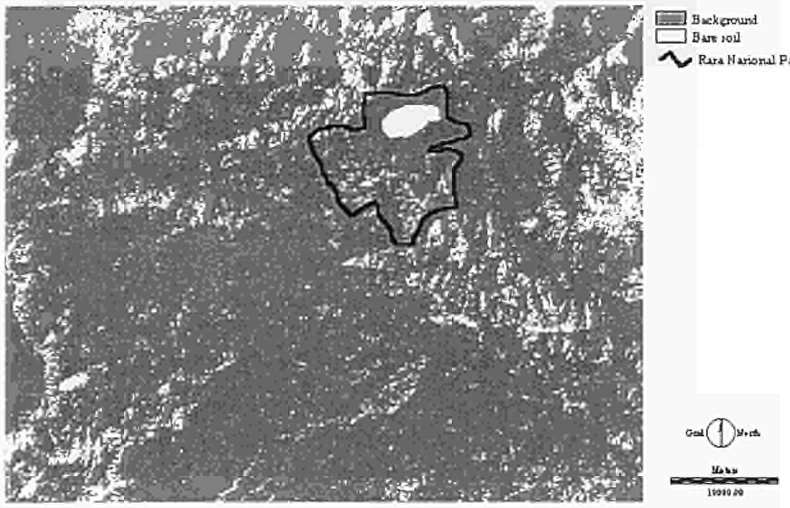

FIGURE 2

Soilmask ETM+ 2000

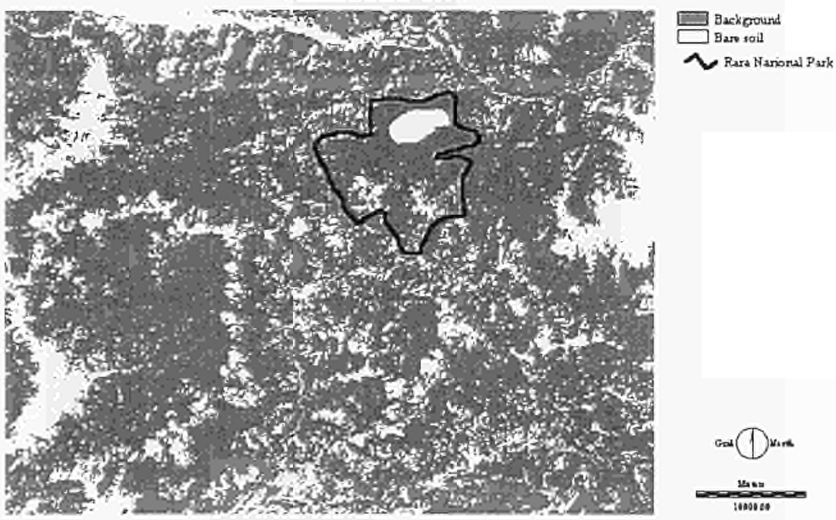

FIGURE 3

Considering the Land Cover Change Map of the Park area and its buffer zones it is evident that almost all the degraded areas are concentrated along the rivers, outside the park's border, where all the villages are located. On the contrary the increase of the forest cover is concentrated in the Park area.

4. Conclusion

The results of this work are confirmed by the past national and international Nepali inventories, and from the scene observed during the expeditions. A rational forest assessment of the area is needed in order to preserve natural resources. The lack of terraced field for agriculture, deforestation, and overgrazing are the main causes of soil loss. The growth of population density of the area increases the environmental effects of human pressure. Soil erosion is natural on steep slopes and heavy precipitation during the monsoon intensifies the process; moreover deforestation and overgrazing have accelerated the soil loss. Any effort towards the development of the area has been hindered by the poor condition of the indigenous population. The relationship between environment and development in highlands of Nepal should be considered to be inverted since some of the environmental stresses there are made of extreme underdevelopment. Poverty is the basic cause of poor land management, the consequence of which is deepening poverty.

References

FAO, 1999. FRA 2000. Annotated Bibliography, Forest Cover Change, Nepal. Working Paper No. 12 (written by H. Ortiz-Chour). Forest Resources Assessment Programme, Rome. pp 3-5.

Gururng, H.B., 1996. Conservation of the Environment in the Nepal Himalayas. ICIMOD Newsletter No.24, April 1996.

Perugini, L. 2001. Analisi dei cambiamenti della copertura forestale nella regione del Karnali (Nepal Occidentale) mediante immagini da satellite. Tesi di Laurea, AA 1999-2000, University of Tuscia, Viterbo, Italy. 118 pp.

Shrestha, T.B. 1985. Vegetation and People of Western Nepal with special reference to Karnali zone, in Nepal-Nature's Paradise. White Lotus Co. Ltd.,Bangkok, Thailand, pp 360-368.

Estimation of forest canopy closure on the Mt Etna Volcano using Landsat TM data and digital ortho-photos

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Abstract

Remotely sensed data and automated classification methods are more and more considered as a complementary tool to traditional photo-interpretation method and field surveys in forests inventory and monitoring.

In this study, the usefulness of remotely sensed data for the estimation of forest canopy closure has been examined using a multi stage classification approach of Landsat TM images and digital ortho-photos.

Supervised classification methods have been applied to the Landsat TM image to identify the forest land of the Mt Etna and to subdivide it into the follow sub-classes: Mediterranean evergreen broadleaves, deciduous broadleaves and coniferous forests. The results have been compared with the existing vegetation map of the study area in order to evaluate the accuracy of the classification.

The NDVI image has been calculated from the Landsat TM image and has been used for the reclassification of the forests into three classes of percentage canopy cover using the forests mask previously generated. Black and white digital ortho-photos of the study area have been used to validate the obtained canopy closure classification and to increase its accuracy from 30 m to 4 m spatial resolution.

Keywords: Forest canopy closure, Mt Etna, Landsat Tm images, digital ortho-photos

1. Introduction

Forest species and forest canopy closure are important variables in forest ecological studies and forest planning and management. Nowadays, information about forest species can be derived from remote sensing imagery using classification methods while canopy closure is usually determined through field surveys.

In this study, the usefulness of remotely sensed data for the estimation of forest canopy closure has been examined in a typical Mediterranean area. In particular, Landsat TM image has been used to identify the forest area and to calculate the NDVI data, which have been used to obtain a forest canopy closure classification of the study area while the black and white digital ortho-photos have been used to increase its accuracy.

FIGURE 1 – Study area location: Mt.Enta

2. Study area

The study area is located in Sicily on the Mt. Etna volcano (Fig.1). In this area, the forests are typically Mediterranean and are mainly dominated by: *Quercus ilex*, *Quercus pubescen s.l.*, *Quercus cerris, Fagus sylvatica, Betula aetnensis* and *Pinus laricio.*

They are characterized by a no uniform canopy cover, which changes in function of the forest type and of the forest structure.

3. Data and methods

A multi stage classification approach (Fig.2) of Landsat TM images and digital ortho-photos has been chosen in order to obtain the forest canopy closure map of the Mt.Etna.

The maximum likelihood supervised classification has been used to extract the forests area from a Landsat TM image of the 10th of August 1994 and to subdivide it into the follow three sub-classes: Mediterranean evergreen broadleaves, deciduous broadleaves and coniferous forests. The training sites, which have been used in both the supervised classifications, have been extracted from the Mt Etna vegetation map (Poli and Patti 2000). This map has been also used to evaluate the accuracy of the obtained classifications.

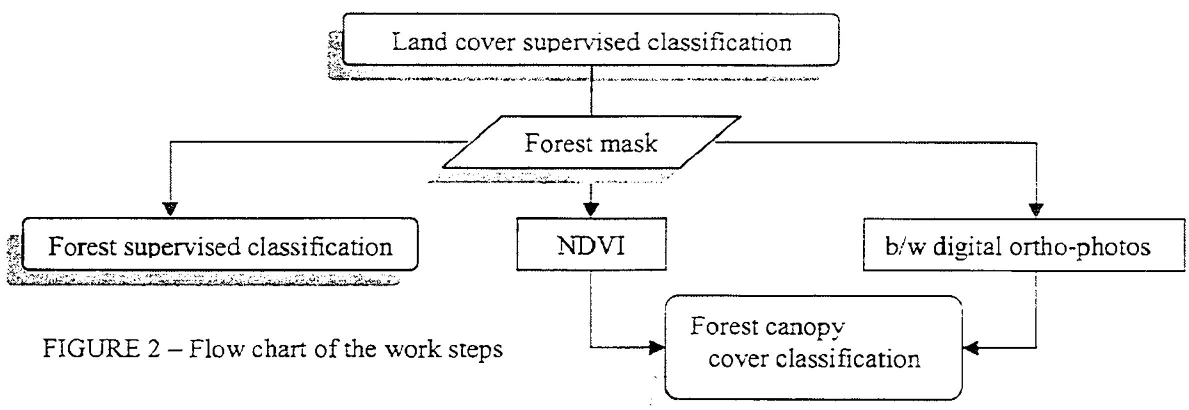
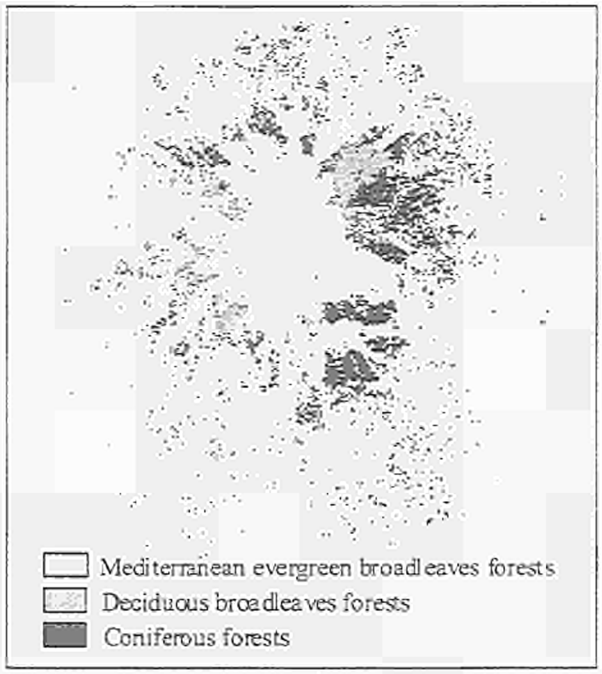


FIGURE 2 – Flow chart of the work steps

FIGURE 3. Forest map of Mt Etna



The forest mask, which had been previously extracted, has been applied to the NDVI image of the Landsat image and to the black and white digital ortho-photos of the 1994. Using sample areas with known forest canopy closure, it was possible to reclassify both the NDVI and digital ortho-photos data into three classes of forests canopy cover (low, middle and high canopy cover). From the analysis of these two maps it was possible to evaluate their accuracy and to analyse the usefulness of the remotely sensed data for the forest canopy closure estimation.

4. Results

The Mt Etna forest map, which is shown in figure 3, has been obtained from the Landsat TM image using two maximum likelihood supervised classifications.

From the first classification, the Mt Etna land cover map has been obtained and the forest area has been extracted and later used as a mask during the following steps.

The second classification has been used to subdivide the forest area into the follow three forest classes: Mediterranean evergreen broadleaves, deciduous broadleaves and coniferous forests.

For reclassify the forestland into these three subclasses, the observed differences in the spectral response of the forest vegetation have been used (Figure 4).

Comparing the obtained land cover map of the study area with the exiting Mt Etna vegetation map (Poli and Patti 2000), the accuracy was approximately 85%.

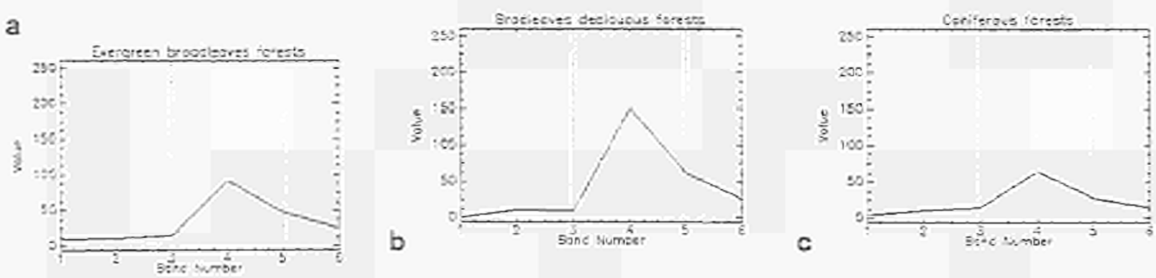


FIGURE 4 – Spectrum response of the Mt Etna evergreen broadleaves (a), deciduous broadleaves (b) and coniferous (c) forests

From the analysis of the second classification, it emerged that some forest areas have been classified erroneously. The first mistake happened in the open deciduous broadleaves formations, which have been classified as evergreen forests, because of the increasing amount of soil and understory brightness. The second mistake occurred in the evergreen and broadleaves forests located on the northern slopes of the small craters, which are present around the Volcano, and on the southern wall of the "Valle del Bove". These forests have been erroneously classified as coniferous forests because of the shadow of the north slopes.

Having identified the main forest types to overall study area, the relation between spectral response and forest canopy cover has been examined.

Using canopy cover ground information of the Mt Etna forests, it was possible to reclassify the NDVI and the black and white digital ortho-photos pixel values into the three canopy cover classes (low, middle and high) which have been previously distinguished (Table 1).

Canopy cover classes	NDVI values	b/w digital ortho photos values
low	0,4 – 0,6	81 - 120
middle	0,61 – 0,8	41 -80
high	0,81 – 1	0 - 40

TABLE 1 – Forest canopy cover classes and correspondent NDVI and b/w digital ortho-photo

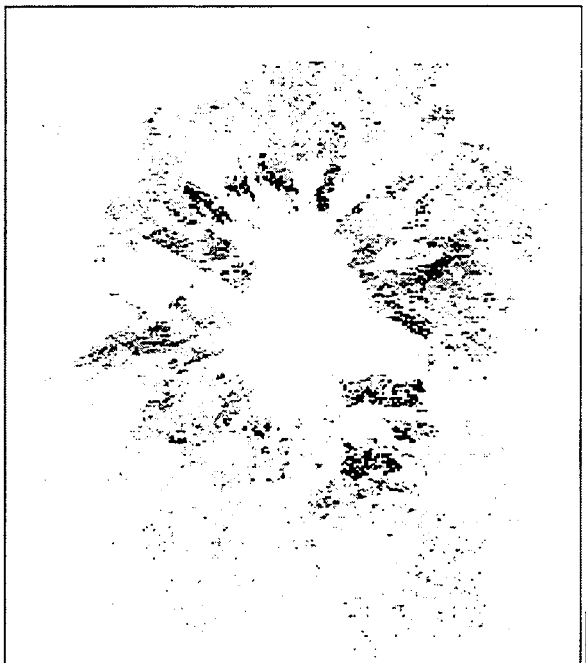


FIGURE 5 – Forest canopy cover maps of the NDVI image

From the analysis of the canopy cover classifications, the classification of the NDVI image (fig.5) shows an overestimation of the low canopy cover class and a underestimation of high canopy cover class for the Mediterranean evergreen deciduous forests and for the coniferous forests. The opposite trend has been found for the deciduous broadleaves forests as it is shows in table 2.

These results are mainly connected to the low resolution of the Landsat data (30 m), which creates mixed pixels.

TABLE 2 – Results of the canopy cover classification for each forest type

Forest types	NDVI image	b/w digital ortho-photos
Mediterranean evergreen broadleaves	Low 32 %	Low 12 %
	middle 56 %	Middle 64 %
	high 12 %	High 24 %
Deciduous broadleaves	Low 7 %	Low 14 %
	Middle 35 %	Middle 41 %
	High 58 %	High 45 %
Coniferous	Low 35 %	Low 22 %
	Middle 56 %	Middle 64 %
	High 9 %	High 14 %

5. Conclusions

From this study, it emerged that the forest canopy closure is closely related to the spectral response of the forest vegetation and that the NDVI values area a good predictor of canopy closure. The NDVI has been chosen because of it is often used in remote sensing of vegetation amount (Franklin 1986) and the biomass may be considered as an indicator of canopy closure (Butera 1986). Beside, it was found that the forest near-infrared reflectance is low for low canopy cover and high for high canopy cover. This is connected to the forest structure. Therefore, when the forest canopy cover increases the near-infrared reflectance increases and it is due to increased of the leaf area or of the stem density (Franklin 1986).

The no very high spatial resolution of the Landsat TM image produced an overestimation of the open forests because of the presence of mixed pixels. For this reason, TM data are not good for predicting forest vegetation amount and relatively characteristics in small stands or single pixel (Franklin 1986). For this reason, it is necessary to use data with finer spatial resolution in order to increase the accuracy of the forest canopy closure estimation and to reduce the mixed pixel influence. Data with finer spatial resolution can be digital ortho-photos, airborne data or new satellite images with higher pixel resolution.

References

Butera, K. 1986 – A correlation and regression analysis of percent canopy closure versus TMS spectral response for selected forest sites in the San Juan national forest, Colorado. IEEE Transaction on geoscience and remote sensing GE-24, 1: 122-129.

Franklin, J. 1986 – thematic mapper analysis of coniferous forest structure and composition. Int.J.Rem.Sens. 7, 10: 1287-1301.

Poli Marchese, E. and Patti, G. 2000. Carta della vegetazione dell'Etna at scale 1:50.000. Selca, Firenze.

Vegetation and floristic composition diversity of the Mt Etna beech (*Fagus* sylvatica L.) forests

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Abstract

Geographical Information System (GIS) is a useful tool for forest assessment and monitoring. In this study, the Mt.Etna beech (Fagus sylvatica L.) communities have been analysed using linear regression analysis and GIS techniques in order to obtain spatial information of their floristic composition and vegetation characteristics variability.

The study has been carried out throughout 250 phytosociological relevées and the vegetation data set has been classified using hierarchical classification method. The geographical position of relevées has been taken using the Global Position System and the database of the relevées has been imported in ArcView 3.2 and has been used for visualising the spatial distribution of the relevées and of their attributes. Furthermore, the Mt.Etna beech forest map has been realized using photo-identification method of aerial photos and later digitalized and georeferenced.

The Shannon and Simpson diversity indices have been calculated and later correlated to the structural characteristics of the stand (canopy cover, mean tree height and mean tree diameter), to the litter characteristics (cover and height) and to the topographic parameters (elevation, slope and aspect).

From this study, it emerged that the Mt.Etna beech communities have a fragmentary distribution around the volcano. It is very difficult to define them sintaxonomically and only in few cases it was possible to identify the association (Aquifolio-Fagetum Gentile 1969). These communities are characterized by a low species richness but their floristic composition is not homogeneous and changes in function of the community structure and of the environmental characteristics.

Keywords: Mt Etna beech forests, biodiversity, regression analysis, GIS

1. Introduction

Some relations between the plant community composition and the environmental characteristics and stand structure have often been documented (Pregitzer et al. 1983; Pitkanen 1997) and the measurements of diversity are frequently considered as good indicators of ecological systems (Magurran 1988).

These relationships may be change in areas subjected to considerable human impact (Brosofske et al. 2001) and their changes are often used as indicators of disturbance of human origin (Mackey and Curie 2000). For this reason, understanding and quantifying the specific diversity is extremely important to better understand the effect of human management on the vegetation (Campanella and Canullo 1999).

In this study, the floristic diversity of the Mt Etna beech forests in relation to the environmental and structural gradients has been analyzed using linear regression analysis and Geographical Information Systems. This allows evaluating how the various factors control species diversity and how much each of these factors contributes to change the floristic composition and the diversity of these forests.

2. Study area

This study has been carried out on Mt.Etna, a volcano located in Sicily (Figure 1). In this area, the beech forests are mainly situated between 1400 and 1900m a.s.l. with the exception of some higher stations at up to 2300m and others lower down at 800-1040 m (Poli et al. 1978, 1979). They have a fragmentary distribution around the volcano and are mainly located on the north, northwestern and northeastern volcano slopes.

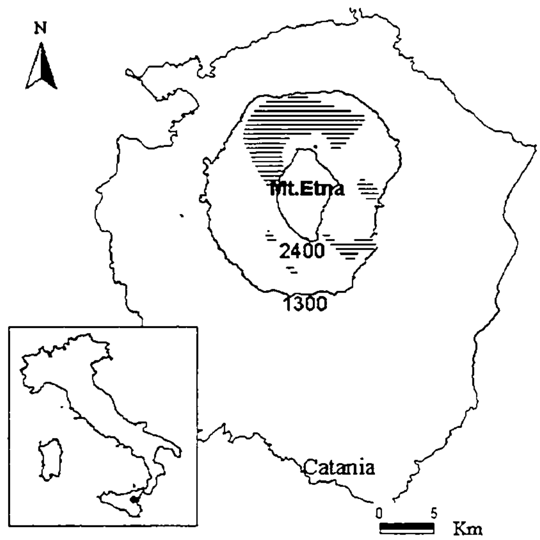

FIGURE 1 – Study area location on the Mt Etna

The Mt. Etna beech forests are particularly interesting because they are relict forests, located at the southern limit of the distribution area of the *Fagus sylvatica* L. species.

On Mt.Etna, they are also subject to unfavourable environmental conditions, such as the volcanic activity, the Mediterranean climate and the high human impact.

3. Materials and methods

Vegetation classification, biodiversity indices and relations between the floristic varibility and the environmental and stand characteristics have been evaluated in this work as showed in the following diagram (Fig.2).

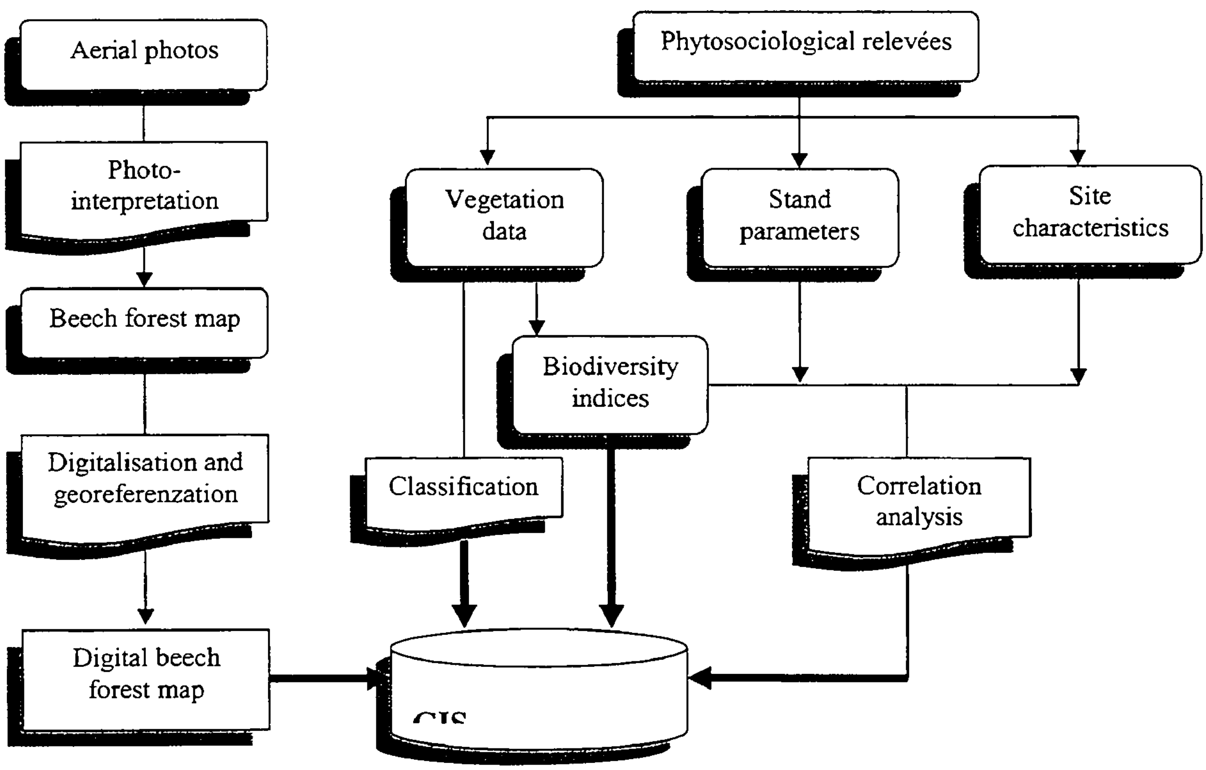

FIGURE 2 – Diagram of the work steps

a) Vegetation analysis

A number of 250 phytosociological relevées has been carried out using the Braun-Blanquet method (1964) in order to analyze the Mt Etna beech forest vegetation. The relevées have been made on the beech belt covering all the different environmental conditions and their geographical position has been taken using a GPS and later verified on the topographic maps.

Each species has been quantified using the cover-abundance scale of van der Maarel (1979) and the hierarchical classification method has been applying to the vegetation data using the Syntax 2000 software. Before to apply the hierarchical clustering, the relevées have been shared into 12 groups in order to increase the accuracy of the classification. The relevées have been shared using the presence or absence of the characteristic species, which have been previously pointed out in these communities (Poli and Puzzolo 1999).

b) Biodiversity and Correlation analysis

After the vegetation classification, the Shannon-Wiener (1948) index and the Simpson's reciprocal (1949) have been calculated. The Shannon index has been calculated as $H= -\Sigma\ p_i \ln p_i$ and the Simpson's reciprocal index as $N_2 = (\Sigma\ p_i^{\ 2})^{-1}$ where pi is the relative abundance of the i-th species. The Shannon index has been later correlated to the forest structure and to the site characteristics using linear regression analysis.

In particular, the data which have been used in the regression analysis are following listed: canopy cover (%), mean tree diameter (cm) and mean tree height (m), elevation about sea level (m), aspect (°N) and slope (°), litter cover (%) and litter height (cm).

c) Geographical Information System

All the data collected and elaborated have been implemented into a database and later imported in a GIS using ArcView 3.2. The relevées distribution and their relative vegetation characteristics, such as floristic composition, species richness and diversity, have been visualized within the beech forest map in order to better understand the spatial variability of these communities around the volcano.

The beech forest map at scale 1:10.000 has been realised through field trips and classical photo-interpretation method of aerial photos and later digitalised, georeferenced and visualized in the GIS.

4. Results

a) Vegetation analysis

From the hierarchical classification of the 250 phytosociological relevées, it emerged that the beech forests of the Mt.Etna are very difficult to define syntaxonomically and that is not always possible to identify the association, the alliance and the order. On the basis of the floristic composition variability it was possible to distinguish six *Fagus sylvatica* L. communities (Poli and Puzzolo 1999).

The results of the classification are shown in figure 3, where the six classified communities are labeled using capital letter (A-F) at the base of the dendrogram while, at the end of each dendrogram line, the number of relevées, which have been previously grouped, is showed.

Only the first group (A) has been classified as *Aquifolio-Fagetum* (Gentile 1969), the beech association widespread on the Southern Apennines and Sicily, even if very few characteristic species of this association have been found.

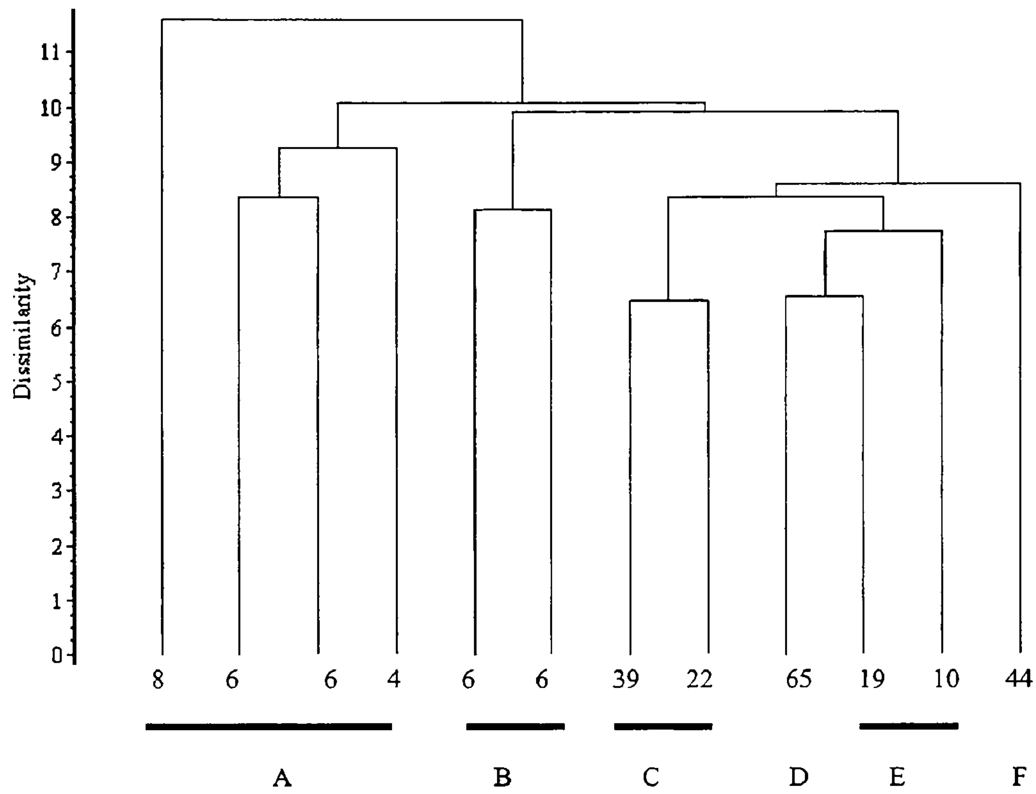

FIGURE 3 – Classification of the Mt Etna beech communities

The second group (B) is characterised by the presence of evergreen forest species of the *Quercetea ilicis* Br.-Bl. 1947 class, with which the beech forests come into clear contact at the lower altitudes. The third group (C) collects relevées characterized by the presence of species of the *Quercetalia pubescentis* Br.-Bl 1931 order.

The relevées of the D group represent the beech forests, which can no longer be ascribed even to the class of which no species is present. The group E collects the beech communities of the higher altitudes, where they are in contact with the herbaceous vegetation of the *Rumici-Astragalion siculi* (Poli 1965) of which some elements are present in the forests of this group. The last group (F) is characterized by the beech forests which can only been classified up to the level of the order or class.

b) Biodiversity and Correlation analysis

A total number of 71 plant species has been recorded in the Mt Etna beech communities but most of these species are not characteristic of these forests. All the six beech communities are characterized by low species richness, their floristic composition is not homogeneous and changes in function of the community structure and of the environmental characteristics.

In Table 1 the mean, minimum and maximum values of each measured parameters are summarized for the six classified communities.

TABLE 1 – Mean, maximum and minimum values of the biodiversity indices and of the environmental and structural characteristics of the six beech communities

		Species richness	Shannon index	Simpson index	Elevation (m a.s.l.)	Slope (°N)	Tree height (m)	Canopy cover (%)	Tree diameter (cm)	Litter cover (%)	Litter height (m)
	Mean	8	0,96	8,46	1566	20	13	98	26	82	5
A	Max	13	1,15	14,00	1760	50	20	98	45	98	10
	Min	3	0,61	3,00	1415	5	8	95	15	30	2
	Mean	8	0,90	7,08	1470	14	12	96	32	92	6
B	Max	11	1,09	12,00	1655	25	15	100	50	98	15
	Min	3	0,55	3,00	1385	5	8	90	20	70	2
	Mean	6	0,79	5,89	1702	15	12	95	24	86	5
C	Max	13	1,17	14,00	2015	50	25	100	70	100	30
	Min	2	0,39	2,00	1400	5	3	80	10	0	1
	Mean	4	0,63	3,67	1811	22	9	91	18	76	3
D	Max	9	1,00	8,00	2280	50	20	100	45	100	15
	Min	2	0,24	2,00	1475	5	2	70	10	0	1
	Mean	6	0,78	5,76	1964	19	6	89	13	73	2
E	Max	10	1,09	11,00	2240	40	15	98	30	98	5
	Min	2	0,39	2,00	1715	5	3	70	5	20	1
	Mean	6	0,77	5,41	1663	17	11	93	23	81	4
F	Max	10	1,04	11,00	2060	40	20	100	50	98	10
	Min	3	0,52	2,00	1400	5	3	70	10	10	1

The values of the Shannon (SH) and Simpson (SI) diversity indices show that the *Aquifolio-Fagetum* community has the highest values while the lowest value is reached by the D group which collects the beech forests, syntaxonomically, less representative (Fig.4).

The diversity indices pointed out that these communities are characterized by very low species diversity. This diversity is mainly connected to the particular conditions to which the beech forests are subjected into the study area.

Both the Shannon and the Simpson diversity indices are significantly correlated ($R^2 = 0,9277$) as is shown in Figure 5. The efficiency of these two indices for the diversity measurements is well documented in the literature (Pitkanen 1998; Neumann and Starling 2001). The Shannon index, which expresses the relative evenness or equitability of the importance values through the whole sequence (Whittaker 1972), is the most used and for this reason it has been chosen for the correlation analysis.

The results of the correlation between the Shannon diversity index and the vegetation characteristics and topographic parameters are showed in table 2.

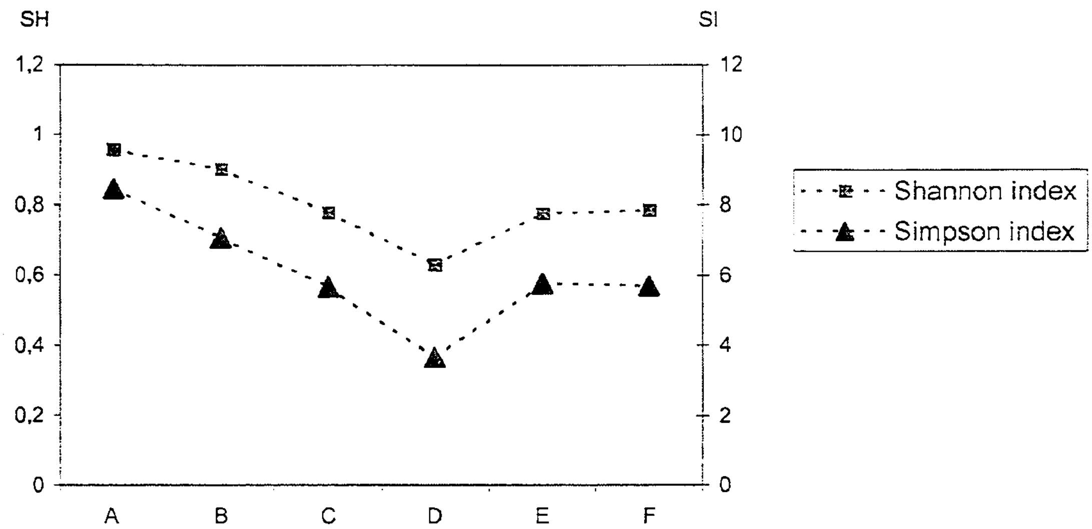

FIGURE 4 – Shannon (SH) and Simpson (SI) mean values of the six beech communities (A-F)

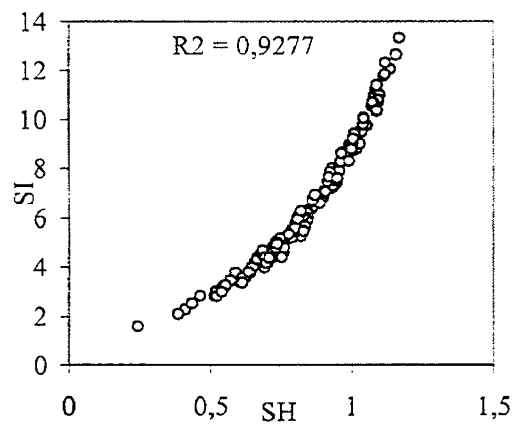

FIGURE 5 – Relation between the indices of Shannon (SH) and of Simpson (SI)

TABLE 2 – Correlation coefficients between the Shannon index of the six beech communities and the measured parameters

	A	B	C	D	E	F
Elevation	-0,129	0,125	-0,287	-0,285	-0,054	-0,022
Slope	-0,346	0,082	-0,188	0,085	0,129	-0,011
Aspect	0,041	-0,193	0,006	-0,248	0,259	-0,137
Tree height	0,243	0,100	-0,139	0,158	-0,086	0,101
Canopy cover	-0,086	-0,261	0,179	0,050	-0,013	-0,162
Tree diameter	0,317	-0,199	0,219	0,202	-0,163	-0,031
Litter cover	-0,172	-0,597	-0,153	-0,061	0,066	-0,390
Litter height	0,002	-0,021	0,189	0,143	-0,215	-0,085

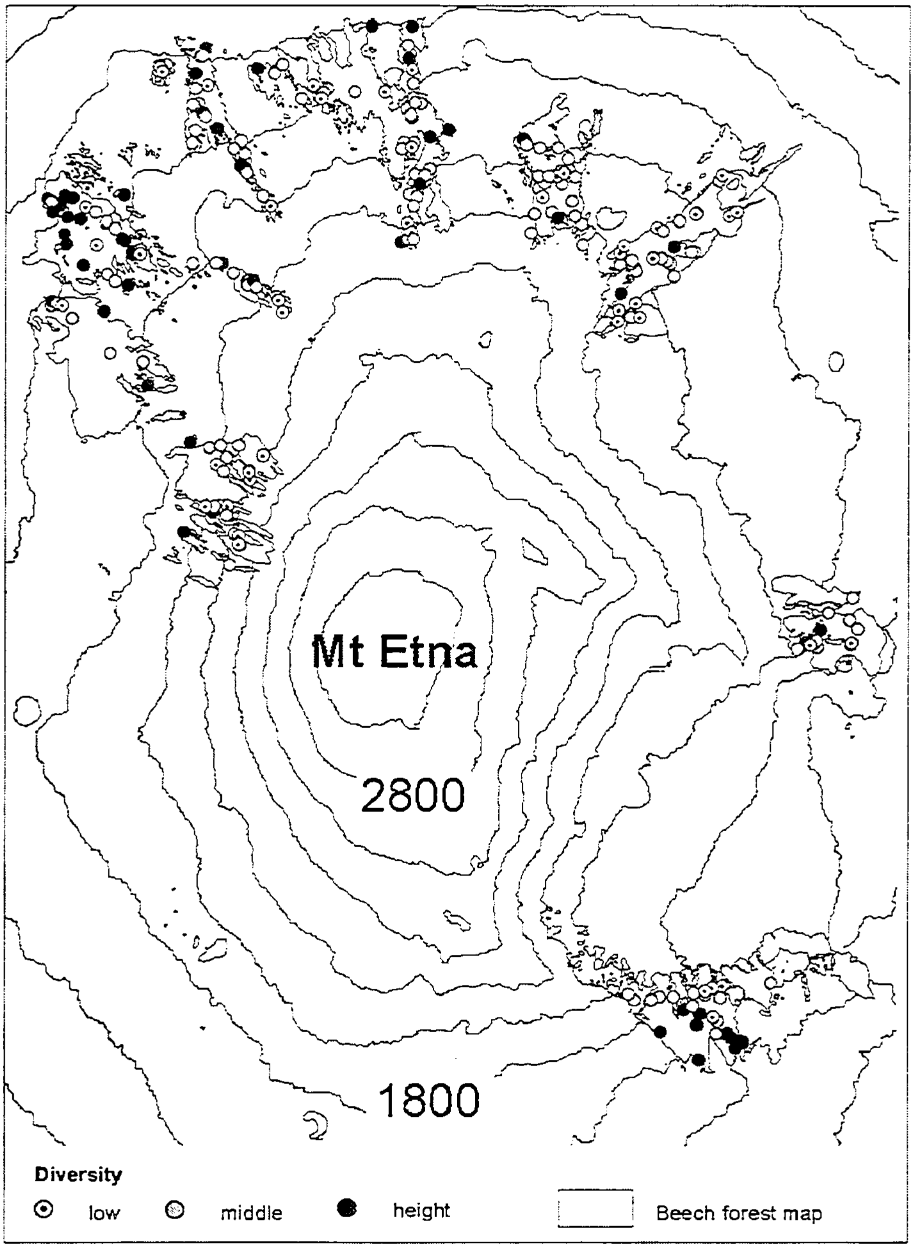

FIGURE 6 – Spatial variability of Shannon index and relative location of the phytosociological relevées on the Mt Etna (3300 n a.s.l.)

These results (Table 2 and Figure 7) indicate that, for the *Aquifolio-Fagetum* community (A), there is a positive correlation between the Shannon index (SH) and the mean tree diameter (0,317) and between SH and the canopy cover (0,243) while the SH values have a high negative correlation with the slope increase (-0,346) and with the litter cover (-0,172).

The communities of the B group, which are characterized by species of the *Quercetea ilicis,* prefer the southernmost aspect and for this reason there is a negative correlation SH-aspect (-0,193). They also show a negative correlation with the tree height (–0,261), with the tree diameter (–0,199) and with the litter cover (-0,597). The communities with the presence of *Quercetalia pubescentis* species (C) are characterized by a negative correlation of the SH with elevation (-0,287), slope (-0,188) and canopy cover (-0,139) and a positive one with the mean tree height (0,179) and mean tree diameter (0,219).

The D group shows a positive correlation with the forest structure. The SH is positively correlated to the canopy cover (0,158) and to the tree diameter (0,202) while it is negatively correlated to the elevation (-0,285) and to the aspect (-0,248). The beech communities of the higher altitudes, which have been collected in the E group, show the opposite behaviour. They have a negative correlation SH-forest structure and a positive correlation SH-slope and SH-aspect.

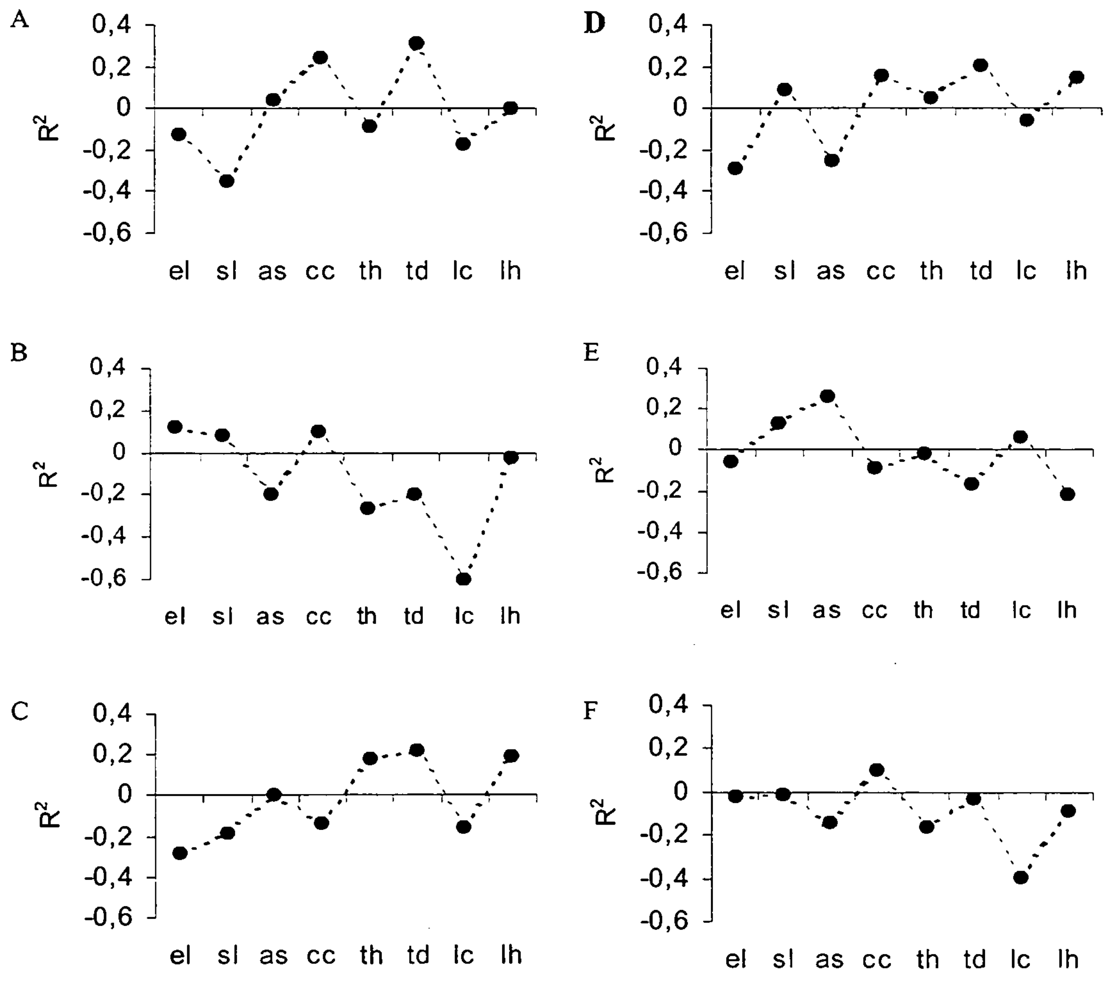

FIGURE 7 – Correlation coefficient values of the six beech communities between the Shannon index and each of the following parameters: el = elevation, sp = slope, as = aspects, cc = canopy cover, th = mean tree height, td = mean tree diameter, lc = litter cover and lh = litter height

The last group (F) is the lowest correlated to all the structural and environmental parameters, it is characterized by a negative correlation between SH and litter cover (-0,39). The negative relation, which has been observed between the SH values and the litter cover of the B and F communities, is probably due to the effect which the beech forest litter has on the growth of the characteristic species of other syntaxa communities, such as *Quercetea ilicis* and *Quercetalia pubescentis*.

5. Conclusions

This study allowed assessing the floristic composition variability and the biodiversity of the Mt.Etna *Fagus sylvatica* forests in relation to their environmental and structural characteristics. Using linear regression analysis and Geographical Information Systems, it was possible to evaluate how the various factors control species diversity and how much each of these factors contributes to change the floristic composition and the diversity of these forests.

The Mt.Etna beech forests are characterized by low species richness and by a not homogeneous floristic composition which changes in function of the vegetation structure (canopy cover, mean tree height and mean tree diameter), of the litter cover and height and of the topographic characteristics (elevation, slope, aspect and volcano slope). The highest values of diversity indices are to be found on the *Aquifolio-Fagetum* community (A), which is, syntaxonomically, the mostly defined vegetation type.

From this study, it also emerged that it is necessary to analyze the relationships between the vegetation characteristics and the environmental parameters, including climate and soil, for improving the forest monitoring and management. In particular, these forests, which are surviving in extreme environmental conditions, have to be managed carefully within the Mt.Etna natural park and have to be protected from the human disturb which can strongly influence the biodiversity of these forests.

References

Brosofske, K.D., Chen, J., Crow, T.R. 2001 – Understory vegetation and site factors: implications for a managed Wiscinsin landscape. Forest Ecology and Management 146: 75-87.

Campanella, G. and Canullo, R. 1999 – Plant biodiversity as an indicator of the biological status in forest ecosystems: community and population level indices. Ann.Ist.Sper.Selv. 30:73-79.

Gentile, S. 1969 – Sui faggeti dell'Italia meridionale. Atti Ist.Bot.eLab.Critt. Univ.di Pavia 5 (6): 207-306

Mackey, R.L. and Curie, D.J. 2000 – A re-examination of the expected effects of disturbance on diversity. Oikos 88 (3): 483-493.

Magurran, A.E. 1988 – Ecological diversity and its measurements. Croom Helt London, 179 p.

Neumann, M. and Starlinger, F. 2001 – The significance of different indices for stand structure and diversity in forests. Forest Ecology and Management 145: 91-106.

Pitkanen, S. 1997 – Correlation between stand structure and ground vegetation an analytical approach. Plant Ecology 131: 109-126.

Pitkanen, S. 1998 – The use of diversity indices to assess the diversity of vegetation in managed boreal forests. Forest Ecology and Management 112: 121-137.

Poli, E., Di Benedetto, L., Ferito, N., Lo Giudice, R. 1978 – Stazioni etnee di faggio a bassa quota. Acc.Gioiena di Sc.Nat.Catania,10, 7: 135-148.

Poli, E., Ferito, N., Lo Giudice, R. 1979 – La vegetazione della Valle San Giacomo (Etna). Acc.Gioiena di Sc.Nat.Catania 10, 7: 253-319.

Poli Marchese, E. and Puzzolo, V. 1999 – Floristic composition, physiognomic and structural aspects of the *Fagus sylvatica* L. forests of the Mt Etna Natural Park (southern Italy). Ann.Bot. LVII: 105-120.

Pregitzer, K.S., Barnes, B.V., Lemme, G.D. 1983 – Relationships of topography to soils and vegetation in an upper Michigan ecosystem. Soil Sci.Soc.Am.J. 47:117-123.

Whittaker, R.H. 1972 – Evolution and measurement of species diversity. Taxon, 21 (2/3): 213-251

Predicting stand structure in Mediterranean conifer and hardwood stands by MIVIS airborne hyperspectral imagery

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Abstract
Hyperspectral images were acquired on June 21st, 2000 by the Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) in order to derive indicators of Mediterranean forest structure.
An extensive field measurement campaign was carried out at San Rossore Reserve (Pisa, Italy) contextually to the flight to provide a ground truth for the airborne data. Measurements focused on 11 stands of various age, comprising both natural hardwoods and pine plantations (Pinus pinea and P. pinaster). For each stand structure parameters (leaf area index, basal area, height, diameter, green canopy depth and stand density) were measured.
The response function of chance correlation to sampling dimension was calculated by means of simulation analysis. Leaf area index was well estimated by the reflectance at 2446 nm (R^2=0.83) and by reflectance at 640 nm normalized with reflectance at 660 nm, ($(Refl_{640}-Refl_{660})/(Refl_{640}+Refl_{660})$) ($R^2$=0.90). Two band vegetation indices (normalized index or simple ratio) can also estimate basal area, diameter, green canopy depth, fraction of green canopy on total height and natural logarithm of stand density with R^2 higher than 0.85.

Keywords: remote sensing, forest, LAI, biophysical parameters, NDVI, hyperspectral imaging spectrometers

1. Introduction

For forest science and their applications the study of stand structural parameters play a prioritary role. A knowledge of stand density, basal area and leaf area index is necessary both for ecosystem understanding and forest management. Leaf area index (LAI, leaf area per unit ground area) is an important canopy parameter needed to compare canopy development or structure over time, under different environmental conditions, or among species, to understand canopy gap dynamics and disturbance and to estimate ecosystem productivity (Landsberg and Gower 1997). Traditionally stand measurements, done by direct field sampling, are time-consuming and provide information limited to small scale. Aerial photographs with high spatial resolution have been used to estimate forest stand parameters as height, crown width and crown closure, and to derive diameter, volume and stocking by regression analysis (Howard 1991) or by image analysis (Pitt et al. 1997).
The improvement of imaging spectrometers and remote sensing techniques offers the opportunity to estimate forest stand parameters from airborne and satellite imagery. Based on experimental and modeling evidence, vegetation reflectance is known to be primarily a function of tissue optical proprieties, canopy biophysical attributes, soil reflectance, illumination conditions and viewing geometry (Ross 1981; Goel 1988; Myneni et al. 1989; Jacquemoud et al. 1992). Spectral bands in the visible and near-infrared (NIR) and short-wave-infrared (SWIR) regions of the spectrum have been used to develop a number of indices for estimating canopy leaf area index (LAI), foliar chemistry and chlorophyll content.
LAI is typically estimated using ratio-based techniques of broadbands, such as the Normalized Difference Vegetation Index (NDVI: e.g. Sellers 1989;Asrar et al. 1989). The physical basis behind this relationship depends on the high spectral contrast between scattered near-infrared (NIR) and absorbed red radiation in canopies. As the number of leaves present in a canopy increases over a unit area, NIR reflectance increases, while red reflectance decreases, resulting in an increase in the ratio. NDVI, while highly successful for agriculture and grassland ecosystems has been found to be less successful in evergreen chaparral and forested ecosystems (Hall et al. 1995). Typically, the relationship between NDVI and LAI becomes progressively more asymptotic at LAI values above three (Sellers 1985), although linear relationships have been observed in conifers at LAI as high as 13 (Spanner et al. 1994).

First-derivative spectra from the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) were successfully used to estimate concentrations of both nitrogen and lignin in forests (Johnson et al. 1994; Martin and Aber 1997). In all cases, spectral bands used for prediction are known to relate to absorption features of relevant chemical bonds. Absorption in the SWIR has been attributed to a number of different molecular bonds: 1620-1685 nm C-H aromatic; 1740 nm C-H and O-H; 1900 nm O-H and C-O combination; 2280 nm C-H (Osborne and Fearn 1986; Murray and Williams 1987; Curran 1989).
This study uses images acquired with high spatial and spectral resolution. Data were collected at a flight altitude of 1.5 and 3.0 Km resulting in image pixel dimension of 2.5 to 5 m and with up to 9 nm FWHM by the 92 channels of the Multispectral Infrared and Visible Imaging Spectrometer (MIVIS) in order to evaluate the possible application in estimating forest structural parameters at stand level.
Our objectives are to obtain hyperspectral indices to predict stand biophysical parameters and to highlight the relationship between MIVIS spectral data and field measures. Singles bands, simple ratio and normalized indices, calculated from the entire spectra acquired, have been related to each biophysical parameter in order to detect the strongest linear correlations. The correlations between biophysical parameters and single wavelengths or vegetation indices (VI) have been compared with the literature and the probability of random association.

2. Methods

2.1 Field study site

Data were collected in the San Rossore Natural Park (43°43' N, 10°20' E), Pisa, Italy. The area is characterized by Mediterranean climate, and covered by pine plantations (*Pinus pinea, P. pinaster*) and mixed hardwoods. The dominating species are english oak (*Quercus robur*), white poplar (*Populus alba*), southern ash (*Fraxinus oxycarpa*), black alder (*Alnus glutinosa*), white hornbeam (*Carpinus betulus*), elm (*Ulmus minor*), and maple (*Acer campestre*).

Eleven stands, belonging to three chronosequences, were chosen to cover the main forest types and the widest possible range of forests structures (4 stands of *Pinus pinea*, 4 stands of *P.pinaster* and 3 stands of hardwoods).

2.2 Field data collection

Field data were collected within a few days of the flight. Various biophysical parameters (stand density, basal area, green canopy depth, breast height diameter, height and canopy LAI) were measured for each stand. Stand basal area was measured by Bitterlich's relascope and stand density was calculated in circular plots of 10 m radius. LAI was estimated by hemispherical photography (Chen et al. 1997). Sampling was carried out in five points per stand, located at the vertices and at the centre of a cross at a distance of 30m from each other. The photographs were taken on black and white film (Kodak T-max, ISO 100) with a Sigma 8 mm fisheye lens. Normally developed negatives were digitized using a Nikon LS-2000 scanner at 2800 dpi and analyzed by the HemiView Canopy Analysis Software (Delta-T Devices, Cambridge, UK).
Fraction of green canopy was calculated by dividing green canopy depth by total height. Leaf area per tree was derived by dividing canopy LAI by stand density.

2.3 Remote sensing campaign

The dataset used in this work was acquired by MIVIS on June 21, 2000. The flights were performed in south to north direction on a Casa 212 airplane over San Rossore (Pisa, Italy) at an altitude of 1500 and 3000 m, respectively. The acquired imageries cover 7 conifer and 3 hardwood stands out of the 11 sampled stands for the 1500 m overflight, and 8 conifer and 2 hardwood stands for the 3000 m overflight.
The MIVIS is an airborne hyperspectral scanner that operates with 92 channels in the visible and near infrared spectral range (400-2500 nm) and with 10 channels in the thermal infrared spectral range (Table 1). The high quantisation accuracy (12 bit), the broad spectral coverage and the good spectral resolution (up to 10 nm in the near infrared) make it a very interesting sensor for many remote sensing applications.
During the campaign a test site was selected on the monitored coastal zone and in-field measurements were carried out in order to collect data for image calibration and pre-processing. The acquired sets of images were radiometrically calibrated (Barducci and Pippi 2001) and the reflectance values were

calculated as a ratio between the radiance measured by the imaging spectrometer and the radiance calculated by MODTRAN ver. 4 (Berk et al. 1989) with the ground albedo set to 1.

2.4 Data analysis and comparison

The radiometrically and geometrically corrected images were registered trough a GIS on the basis of a 1:10,000 digitized map of the area using the ENVI package (Research Systems Inc., Boulder, USA). The first degree polynomial warping with nearest neighbour resampling was used.
Each study plot was marked out by a Region Of Interest (ROI), and fifty spectra were randomly sampled within each ROI and averaged. Spectra were analyzed both in reflectance and in absorptance, obtained applying the log(1/reflectance) transformation. Linear regression was used to detect associations between each of the measured biophysical parameters and spectral data. The analysis was performed with single bands and couples of bands expressed as simple ratio or normalized indices. Three bands were excluded (1325, 1375 and 1425 nm) because highly noisy. As result, a total of 89 single bands and 3916 normalized indices were tested over 10 field sites.

In order to quantify the problem of chance correlation, random values were generated for an increasing number of sampling areas and related to vegetation spectra sampled within the eleven ROIs. For each simulation run the best Pearson's coefficient (R^2) obtained for single band and normalized indices was calculted. Fifty simulation runs were performed in order to calculate the average value (m) and the standard deviation (sd) of the best R^2 in function of the number of sampling areas. Assuming a normal distribution of R^2 coefficients for each sampling dimension the 95% confidence limits of obtaining for chance the observed R^2 were calculated as $m \pm 1.96sd$.

TABLE 1: MIVIS main characteristics.

Type	Whisk-broom Imaging Spectrometer
Number of channels	102
Spectral coverage and resolution	0.43-0.83 µm in 20 channels with 20 nm FWHM 1.15-1.55 µm in 8 channels with 50 nm FWHM 1.985-2.479 µm in 64 channels with 9 nm FWHM 8.21-12.7 µm in 10 channels with 360 nm FWHM
Field of view (FOV)	71.06°
Instantaneous FOV (IFOV)	2.0 mrad
Angular sampling step	1.64 mrad
Cross-track pixel	755
Digitalisation accuracy	12 bit
Estimated Signal to noise ratio (SNR)	30-150 depending on channel

3. Results and discussions

3.1 Estimation of the effect of chance correlation

The high number of bands and indices require an intense field work in order to reduce the problem of chance correlation. With 10 areas sampled, the maximum R^2 obtained by chance was 0.67 with a standard deviation of 0.08 for the 3916 indices and 0.50 (± 0.15 sd) for the 89 single bands (Figure 1). Pearson's coefficients higher than 0.794 for single bands and 0.827 for normalized indices are expected by chance with a probability of 2.5% of cases. The maximum R^2 (m) decreases rapidly with the increase of the number of sampled areas (n) at a rate given by the power equation $m = 4.8484n^{-0.9898}$ for single band and $m = 7.2831n^{-0.9965}$ for nomalized index.

3.2 LAI and stand structural parameters

Average and standard deviation over the 11 stands were 3.0±1.0 m^2 m^{-2} for canopy LAI, 30.8±13.9 cm for diameter (DBH), 16.0 ±8.1 m for height (H), 8.3±6.0 m for green canopy depth (GCD), 0.54±0.23 m m^{-1} for the fraction of green canopy on total height (GCD_{Fr}), 38.3±12.7 m^2 ha^{-1} for basal area (BA), 79.6±84.4 m^2 leaf area per tree (a_f), 1338±2367 ha^{-1} for tree density (n) and 6.48+1.10 ha^{-1} for the logarithm of tree density [ln(n)].
All the biophysical parameter measured are normally distributed, except stand density and leaf area per tree for which the Shapiro-Wilk test for normal distribution showed a highly significant W value (p<0.01) (Shapiro et al. 1968). In order to obtain normal data tree density was transformed as logarithm.
Canopy LAI was not linearly related to any of the other biophysical parameter. Leaf area per tree was linearly related to breast height diameter (R=+0.93**, n=11, a_f=5.16DBH-79.92), as well as height, (R=0.82**, n=11, H=3.797+0.384DBH). Green canopy depth is related to height (R=+0.83**, n=11, GCD=-1.045+0.566H); fraction of green canopy on total height is related to basal area, (R=-0.82**, n=11, GCD_{Fr}=1.15-0.016BA); diameter is related to the logarithm of tree density [R=-0.94**, n=11, DBH=123.19-14.08ln(n)].

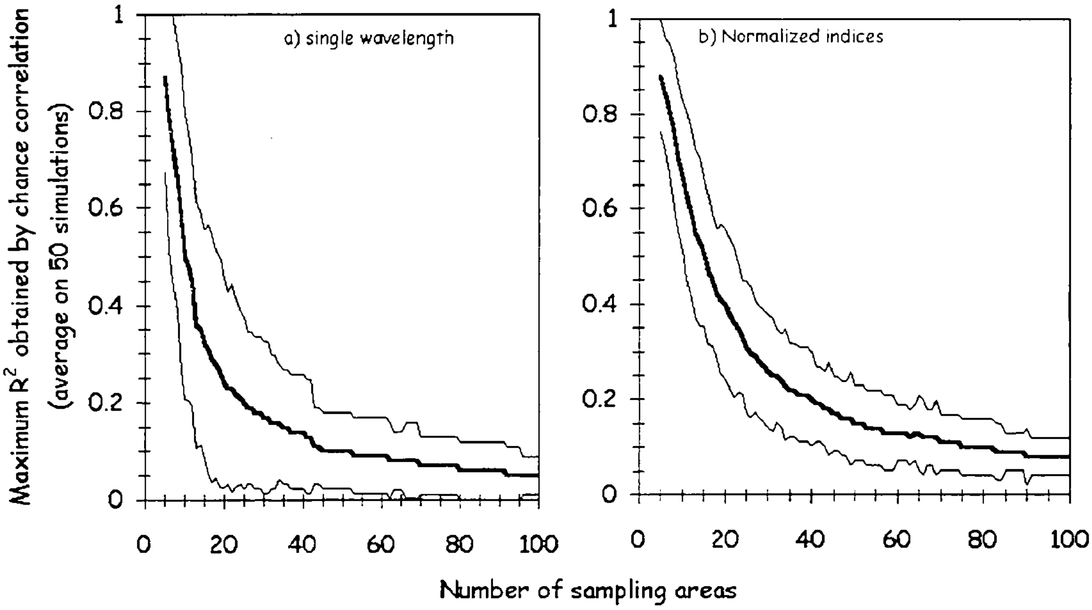

FIGURE 1. Response function of the number of sampling areas on the maximum R^2 coefficient obtained by chance correlation between randomly generated numbers and vegetation reflectance spectral bands (89 values) and normalized indices (3916 values). The maximum R^2 averaged over 50 simulation runs (bold line) and the 95% confidence limits (solid line) are reported in the graph for single bands (a) and normalized indices (b).

Although all the vegetation types have relatively similar spectra proprieties – large absorbtion in the visible and SWIR regions and large reflectance in NIR - different vegetation types have special characteristics depending on the canopy architecture and biochemical contents (Fig. 2)

3.2.1 LEAF AREA INDEX

Long-term monitoring would require robust measurements of LAI, as do comparisons of LAI among stands or communities. Leaf area index is generally estimated by Normalized Difference Vegetation Index (NDVI), defined as (R_{NIR}-R_{RED})/(R_{NIR}+R_{RED}), by contrasting the strong chlorophyll absorption in the red wavelengths with the high reflectance in the near-infrared wavelengths (Rouse et al. 1973). Although widely used in the estimation of LAI and chlorophyll contents, it has been found to saturate at medium to high concentrations of the pigment and LAI values (Asrar 1989). Most of the studies on LAI refer to broadband imagery (Broge and Leblanc 2000). With hyperspectral sensor MODIS Gitelson et al. (1996) found the best correlation between LAI and green-NDVI, defined as NDVI=(R_{NIR}-R_{GREEN})/(R_{NIR}+R_{GREEN}). By using the green reflectance peak near 550 nm, they found that the green-NDVI is sensitive to a much wider range of chlorophyll concentrations than the original NDVI.
In our dataset LAI ranges from 1.2 to 3.9 in conifer stands and from 2.6 to 4.5 in hardwoods. This

variability is explained by the single band centered at 2446.5 nm. The R^2 of 0.83 is higher than what expected by chance correlation. Normalizing the 2446.5 nm band with bands in the NIR from 740 to 1175 nm R^2 coefficients are always greater than 0.75, with the maximum R^2 at 760 nm (R^2=0.80) for 1500 m overflight. Consistent but slightly lower R^2 were obtained for the 3000 m overflight, (Figure 3) The signal at 2446.5 nm has a marked absorptance feature, and corresponds to a reflectance peak, that decreases at increasing LAI. This wavelength was reported to have a high absorption coefficient for lignin-cellulose content (Dawson et al. 1999). At low LAI the effect of non-photosynthetic vegetation on spectra is expected to be higher.

TABLE 2. Correlation between biophysical parameters and single wavelength, normalized and simple ratio indices expressed as reflectance or absorptance. Best Pearson's coefficients (R^2) are reported for the two altitude of overflights. Absorptance features determined in laboratory studies, (Dawson et al. 1999;Curran et al. 2001) on dry leaf powder centered at 1510 nm for aminoacid, at 2000 nm for starch, at 2066nm for cellulose, at 2186 nm for nitrogen and at 2266 nm for lignin are signed with the @A, @St, @C, @N, @L, respectively.

Reflectance	Single band		Normalized index			Simple ratio		
1500 m	R^2	WL, nm	R^2	WL, nm	WL, nm	R^2	WL, nm	WL, nm
LAI, $m^2\ m^{-2}$	0.83	2446	0.90	640	660	0.90	640	660
Basal area, $m^2\ ha^{-1}$	0.39	2412	0.85	2172@N	2220@N	0.85	2172@N	2220@N
Height, m	0.65	2412	0.79	1525@A	2260@L	0.79	1525@A	2260@L
Diameter, cm	0.48	2370.5	0.86	660	680	0.86	660	680
Green canopy depth, m	0.53	660	0.87	2196@N	2115	0.89	2196@N	2115
GCD_{Fr}, $m\ m^{-1}$	0.51	2236	0.96	2296	540	0.97	2296	540
Ln of tree density, ha^{-1}	0.65	2370	0.84	2188@N	2196@N	0.86	2188@N	2196@N
3000 m	R^2	WL, nm	R^2	WL, nm	WL, nm	R^2	WL, nm	WL, nm
LAI, $m^2\ m^{-2}$	0.73	2446	0.84	620	680	0.85	620	680
Basal area, $m^2\ ha^{-1}$	0.85	2014@St	0.92	700	2384	0.92	700	2384
Height, m	0.52	2446	0.82	2268@L	2391	0.83	2268@L	2391
Diameter, cm	0.31	2419	0.57	2355	2377	0.57	2355	2377
Green canopy depth, m	0.52	740	0.82	2252@L	2370	0.83	2252@L	2370
GCD_{Fr}, $m\ m^{-1}$	0.93	1525@A	0.98	700	2268@L	0.97	700	2268@L
Ln of tree density, ha^{-1}	0.48	2453	0.66	2391	2091	0.66	2391	2091
Absorptance	Single band		Normalized index			Simple ratio		
1500 m	R^2	WL, nm	R^2	WL, nm	WL, nm	R^2	WL, nm	WL, nm
LAI, $m^2\ m^{-2}$	0.81	2446	0.87	640	660	0.87	640	660
Basal area, $m^2\ ha^{-1}$	0.35	2412	0.81	2082	700	0.81	2082	700
Height, m	0.71	1998@St	0.80	2363	2082	0.80	2363	2082
Diameter, cm	0.47	2370	0.83	680	660	0.83	680	660
Green canopy depth, m	0.61	1998@St	0.84	2031	2363	0.86	2031	2363
GCD_{Fr}, $m\ m^{-1}$	0.46	2236	0.95	540	2333	0.95	540	2333
Ln of tree density, ha^{-1}	0.61	2370	0.91	2188@N	2196@N	0.91	2188@N	2196@N
3000 m	R^2	WL, nm	R^2	WL, nm	WL, nm	R^2	WL, nm	WL, nm
LAI, $m^2\ m^{-2}$	0.72	2446	0.91	2412	2031	0.92	2412	2031
Basal area, $m^2\ ha^{-1}$	0.88	2384	0.91	2384	700	0.93	2384	700
Height, m	0.46	1998@St	0.81	2391	2252@L	0.82	2391	2252@L

Diameter, cm	0.23	2419	0.69	$2196^{@N}$	$2252^{@L}$	0.69	$2196^{@N}$	$2252^{@L}$
Green canopy depth, m	0.55	740	0.85	$2058^{@C}$	2115	0.85	$2058^{@C}$	2115
GCD_{Fr}, m m^{-1}	0.93	$2268^{@L}$	0.98	$2268^{@L}$	700	0.98	$2268^{@L}$	700
Ln of tree density, ha^{-1}	0.33	2419	0.62	$2252^{@L}$	2220	0.62	$2252^{@L}$	2220

The indices that performed the best correlations for LAI were composed by all the bands after the green peak (from 580 to 680nm, with the best result at 620 nm) normalized with the chlorophyll absorption bands at 660 and 680 nm (Figure 4).

All the results are consistent with the different altitude of the overflights (Figure 4, Table 2). The higher overflight has a lower ground resolution (5 m x 5 m, instead of 2.5 m) and a different sample composition in which a hardwood area was substituted by a conifer stand.

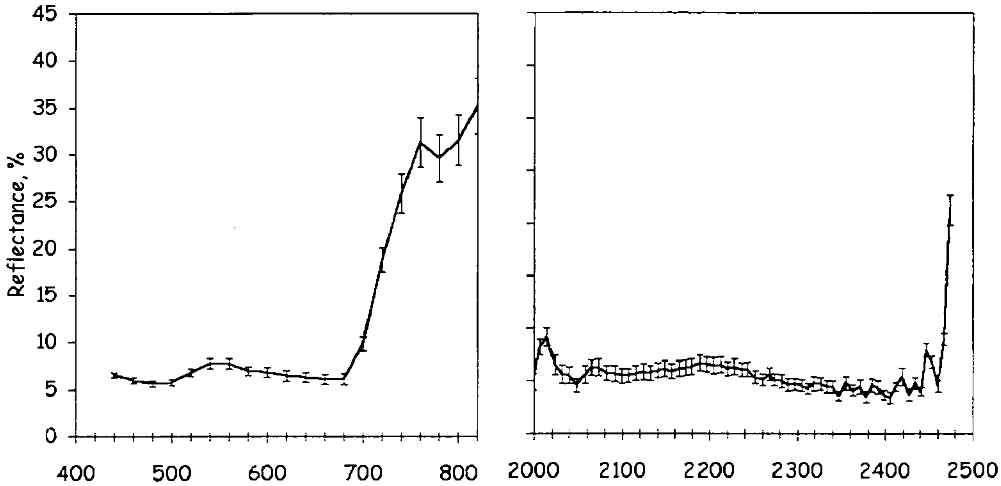

FIGURE 2. Average and standard error for vegetation spectrum over the 11 stands.

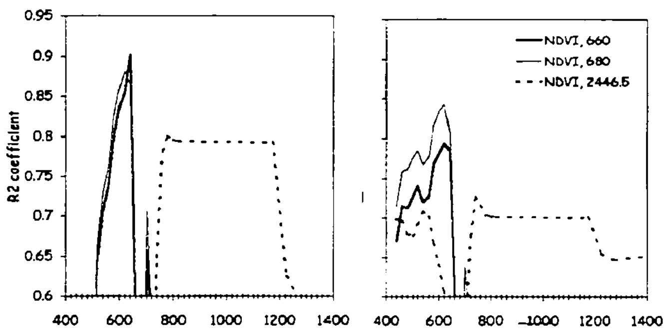

FIGURE 3. Correlogram for LAI and normalized indices made with reflectance at 2446, 660 and 680 nm for the 1500 m (left) and 3000 m (right) overflights.

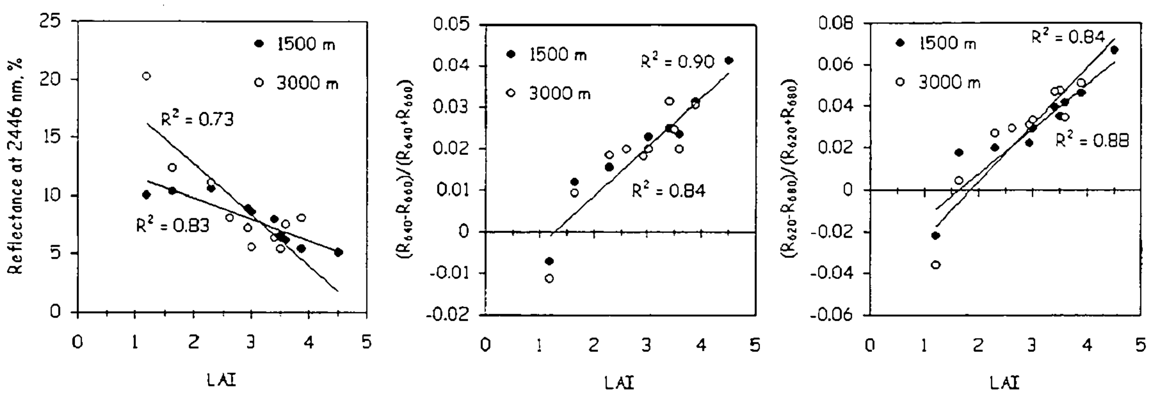

FIGURE 4. Relationship between LAI and reflectance at 2446 nm and LAI and the best normalized indices: $(R_{640}-R_{660})/(R_{640}+R_{660})$ and $(R_{620}-R_{680})/(R_{620}+R_{680})$ for 1500 m and 3000 m overflights. The normalized index $(R_{640}-R_{660})/(R_{640}+R_{660})$ has the same regression line for the two flight altitudes.

3.2.2 STAND STRUCTURAL PARAMETERS

For the 1500 m overflight, the stand structural parameters (basal area, height, diameter, green canopy depth, fraction of green canopy on total height and logarithm of tree density) showed a correlation with single wavelength reflectance (or absorptance) lower than the R^2 expected by chance correlation.

Once the reflectance (or absorptance) is expressed as normalized indices or simple ratios, the R^2 in the correlations arise over the expected value by chance correlation, except for height (Table 2). The fraction of green canopy on total height is particularly well related with R^2 higher than 0.95 for both flights. The retrieval of diameter and the logaritm of tree density by remote sensing has not given coherent results between the two flight altitudes, with the best results for the 1500 m overflight.

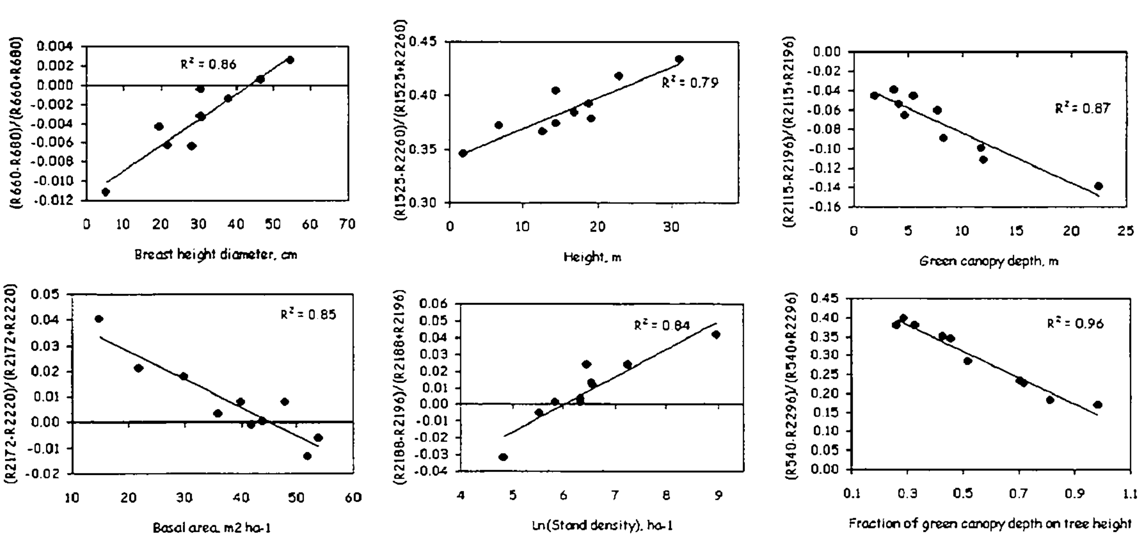

FIGURE 5. Relationship between normalized indices and stand structural parameters

Most of the strongest correlations were in the SWIR region of the spectrum. This region is highly influenced by water content and by biochemical components of leaf and plant tissue. Nitrogen, cellulose and lignin have absorption features in this part of the spectrum (Gastellu-Etchegorry and Bruniquel-Pinel 2001; Curran et al. 2001). A high absorption coefficient in the range 2300-2500 for lignin-cellulose content was also reported (Dawson et al. 1999).

Our results showed that some of the significative bands are near to absorption features of chlorophyll (660 and 680 nm), aminoacids (1510 nm), starch (2000 nm) and nitrogen (2186 nm), (Curran et al. 2001); cellulose (2066 nm) and lignin (2266 nm), (Kokaly and Clark 1998; Kokaly and Clark 1999), Table 2. These biochemical compounds have an important role in providing information to a better understanding of community relationships and function. Chlorophyll absorption bands enter in the indices to estimate LAI. Lignin gradients in the upper canopy surface, as measured by spaceborne sensors, was suggested to

be related more closely to the architectural distribution of foliar and stem biomass than to soil nutrient conditions (Roberts et al. 1990).
In conclusions, the biophysical structure of forest stands is captured by SWIR bands with high spectral resolution and by the range 540-680 nm in the visible. The good correlations highlighted between the VI and the ground data give a basis for mapping stand structural and biochemical characterisitcs.

Acknowledgments
This study was founded by the Italian Space Agency (Project "*Valutazione dei nuovi sensori aerospaziali*") and by the Italian Ministry of Research (COFIN 2000 MURST Project "*Bilancio e accumulo del carbonio negli ecosistemi forestali*"). Ours sincere thanks to Gherardo Chirici from GeoLAB for the help with GIS and cartography; Dr. Federico Magnani for his contribution to data analysis; the administrators and the foresters of San Rossore Reserve for the collaboration and the help in the field.

References

Asrar, G. 1989. Theory and Applications of Optical Remote Sensing. New York: J. Wiley.

Asrar, G., R. B. Myneni, E. T. Kanemasu. 1989. Estimation of plant-canopy attributes from spectral reflectance measurements. *In* Theory and Applications of Optical Remote Sensing, pp. 252-296. Edited by G. Asrar . New York: J. Wiley.

Barducci, A., I. Pippi. 2001. Analysis and reaction of systematic disturbances in hyperspectral remotely sensed images of the earth. Applied Optics - LP 40: 1464-1477.

Berk, A., Bernstein L.S., and D. C. Robertson. MODTRAN: a moderate resolution model for LOWTRAN 7. 38. 1989. Hanscom Air Force Base, MA: Air Force Geophysics Laboratory.

Broge, N. H. and E. Leblanc. 2000. Comparing prediction power and stability of broadband and hyperspectral vegetation indices for estimation of green leaf area index and canopy chlorophyll density. Remote Sensing of Environment 76: 156-172.

Chen, J. M., P. M. Rich, S. T. Gower, J. M. Norman, and S. Plummer. 1997. Leaf area index of boreal forests: theory, techniques and measurements. Journal of Geophysical Research 102: 429-443.

Curran, P. J. 1989. Remote sensing of foliar chemistry. Remote Sensing of the Environment 30: 271-278.

Curran, P. J., J. L. Dungan, and D. L. Peterson. 2001. Estimating the foliar biochemical concentration of leaves with reflectance spectroscopy. Testing the Kokaly and Clark methodologies. Remote Sensing Environment 76: 349-359.

Dawson, T. P., P. J. Curran, P. R. J. North, and S. E. Plummer. 1999. The propagation of foliar biochemical absorption features in forest canopy reflectance: a theoretical analysis. Remote Sensing of Environment 67: 147-159.

Gastellu-Etchegorry, J. P. and V. Bruniquel-Pinel. 2001. A modeling approach to assess the robustness of spectrometric predictive equations for canopy chemistry. Remote Sensing of Environment 76: 1-15.

Gitelson, A. A., Y. J. Kaufman, and M. N. Merzlyak. 1996. Use of a green channel in remote sensing of global vegetation from EOS-MODIS. Remote Sensing of Environment 58: 289-298.

Goel, N. S. 1988. Models of vegetation canopy reflectance and their use in estimation of biophysical parameters from reflectance data. Remote Sensing Reviews 4: 1-212.

Hall, F. G., Y. E. Shimabukuro, and K. F. Huemmrich. 1995. Remote sensing of forest biophysical structure using mixture decomposition and geometric reflectance models. Ecological Applications 5: 993-1013.

Howard, J. A. 1991. Remote sensing of forest resources. Theory and application. Remote Sensing Applications. London, New York: Chapman and Hall.

Jacquemoud, S., F. Baret, and J. F. Hanocq. 1992. Modeling spectra and bi-directional soil reflectance. Remote Sensing of Environment 41: 123-132.

Johnson, L. F., C. A. Hlavka, and D. L. Peterson. 1994. Multivariate analysis of AVIRIS data for canopy biochemical estimation along the Oregon transect. Remote Sensing of Environment 47: 216-230.

Kokaly, R. F. and R. N. Clark. 1998. Spectroscopic determination of leaf biochemistry: use of normalized band-depth and laboratory measurements and possible extension to remote sensing measurements. *in* JPL, Pasadena, USA: Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) Airborne Geoscience Workshop.

Kokaly, R. F. and R. N. Clark. 1999. Spectroscopic determination of leaf biochemistry using band-depth analysis of absorption features and stepwise multiple linear regression. Remote Sensing of Environment 67: 267-287.

Landsberg, J. J. and S. T. Gower. 1997. Applications of Physiological Ecology to Forest Management. San Diego: Academic Press.

Martin, M. E. and J. D. Aber. 1997. High spectral resolution remote sensing of forest canopy lignin, nitrogen, and ecosystem processes. Ecological Applications 7: 431-443.

Murray, I. and P. C. Williams. 1987. Chemical principles of near-infrared technology. Pages 17-34 *In* Near-infrared technology in the agricultural and food industries. Edited by P. Williams and K. Norris. St.Paul, Minnesota, USA: American Association of Cereal Chemist.

Myneni, R. B., J. Ross, and G. Asrar. 1989. Review on the theory of photon transport in leaf canopy. Agricultural and Forestry Meteorology 45: 1-153.

Osborne, B. G. and T. Fearn. 1986. Near-infrared spectroscopy in food analysis. Harlow, Essex,UK: Longman Scientific and Technical Publishing.

Pitt, D. G., R. G. Wagner, R. J. Hall, D. J. King, D. G. Leckie, and U. Runesson. 1997. Use of remote sensing for forest vegetation management: A problem analysis. Forestry Chronicle 73: 459-477.

Roberts, D. A., M. O. Smith, J. B. Adams, D. E. Sabol, A. R. Gillespie, and S. C. Willis. 1990. Isolating woody plant material and senescent vegetation from green vegetation in AVIRIS data. *In* "Proc., Airborne Sci. Workshop," pp, 42-57. Jet Propulsion Laboratory, Pasadena, California.

Ross, J. 1981. The Radiation Regime and Architecture of Plant Stands. The Hague, The Netherlands: Dr W. Junk Publishers. 391 p.

Rouse, J. W., R. H. Hass, J. A. Shell, and D. W. Deering. 1973. Monitoring vegetation systems in the great plains with ERTS. Pages 309-317 *In* Third ERTS Symposium, NASA SP-351. Washington DC: NASA.

Sellers, P. J. 1985. Canopy reflectance, photosynthesis and transpiration. International Journal of Remote Sensing 6: 1335-1372.

Sellers, P. J. 1989. Vegetation-canopy spectral reflectance and biophysical processes. Pages 297-335 *in* G. Asrar, ed. Theory and Applications of Optical Remote Sensing. New York: J. Wiley.

Shapiro, S. S., M. B. Wilk, and H. J. Chen. 1968. A comparative study of various tests of normality. Journal of the American Statistical Association 63: 1343-1372.

Spanner, M., L. Johnson, J. Miller, R. Mccreight, J. Freemantle, J. Runyon, P. Gong. 1994. Remote sensing of seasonal leaf area index across the Oregon transect. Ecological Applications 4: 258-271.

Relationship between SPOT-2 HRV 2 data and forest stand parameters in a managed Pine plantation

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Abstract

Satellite data potentially provide a useful tool for estimating forest stand characteristics and for monitoring changes. Traditional forest survey methods involve time-consuming measurements of a large number of trees; remotely sensed data may enable stand characteristics to be estimated very rapidly over large areas and with a minimum of ground data collection. The objective of this study was to assess the ability of remote sensing data to provide an estimate of forest structural variables for forest management.

This paper evaluates the relationships between data recorded by SPOT 2 HRV 2 multispectral image and four stand parameters (tree top height, mean diameter, basal area and yield class). Secondary data on forest management were derived from compartment records supplied by the Forestry Commission. The field site selected was the intensively managed Kings Forest, located in East Anglia, UK. The forest is dominated by even-aged compartments of coniferous species mainly of Corsican Pine (Pinus nigra var. maritima) and Scots Pine (Pinus sylvestris), and comprises 213 compartments covering 2334 ha.

This study estimated forest cover changes using Normalised Difference Vegetation Index (NDVI) values derived from spectral reflectance measurements. Regression analysis was carried out to determine the relationships between NDVI and the selected forest parameters. The study found that NDVI changed spatially due to differences in the age of pine trees and background influences such as the density of understory vegetation. NDVI values ranged from 0.235 to 0.831 overall, but only from 0.431 to 0.779 in the Pine plantation site. The results of comparing NDVI and the forest stand parameters were encouraging. There were high positive correlations of 0.73, 0.76, 0.70 between mean NDVI and top tree height, mean diameter and basal area respectively, which were significant at the 95% confidence level, but a very low negative correlation of -0.13 was found between mean NDVI and yield class. The high correlation of NDVI with structural variables implies that NDVI could be an effective technique for accruing information on stand parameters for forest management.

Keywords: Normalised Difference Vegetation Index, Spatial changes, Temporal changes and Structural variables

1. INTRODUCTION

Satellite data have been used to provide estimate of forest characteristics including stand density and height (De Wulf et al. 1990), Leaf Area Index (Spanner et al. 1990) and forest understory (Slenback and Congalton 1990). Image data recorded from SPOT provide a potentially useful tool for estimating forest stand characteristics and for monitoring changes in these characteristics. For forest planning and management purposes, established methods for forest survey involve time consuming measurements of a large number of trees. Remotely sensed data may enable stand characteristics to be estimated very rapidly over large areas with a minimum of ground data collection. The Normalised Difference Vegetation Index (NDVI) can be calculated from the combination of red and near-infrared bands of satellite images. The red band is strongly correlated to the chlorophyll content while the near-infrared band is controlled by the LAI and density of green vegetation (Bannari et al. 1995). These remote sensing methods can be integrated with extensive ancillary secondary data in a Geographic Information System

(Morrison 1990; Morrison et al. 1991; Congalton et. al. 1993) for quantitative and qualitative assessment of forest stand parameters in forest management.

This paper assesses the ability of remote sensing data to provide an estimate of forest structural variables for forest management. Forest cover changes are estimated using Normalised Difference Vegetation Index (NDVI) values derived from spectral reflectance measurements by the SPOT satellite acquired in 1996 over a forest plantation in East Anglia (UK). The success of the remote sensing in identifying forest stands was evaluated in the GIS (MapInfo and ARC VIEW), and overlay operations were performed on the ground-derived forest map supplied by the Forestry Commission.

2. STUDY SITE INFORMATION

The study area selected was the Kings Forest, situated to the south of Thetford forest in East Anglia. (50^0 20' N, $0^0$38' E), containing 213 compartments covering 2334 ha. of mainly coniferous trees. The Kings Forest is a forest plantation intensively managed for timber production by the Forestry Commission, from whom maps and records were obtained. The forest was originally planted in the 1920s, through the afforestation of heath land and low-grade agricultural land and some areas are now in their third rotation. Thinning treatments have been carried out in the past ten years by selective felling of intermediate-sized rows of trees. Felling management started in 1960. Today the forest is dominated by single-species, even-aged compartments, mainly of Corsican Pine (*Pinus nigra var. maritima)* and Scots Pine (*Pinus sylvestris*), with a much smaller number of compartments of broad-leaved species such as Beech *(Fagus sylvatica*) and an understory of brambles, bracken, ferns and grasses.

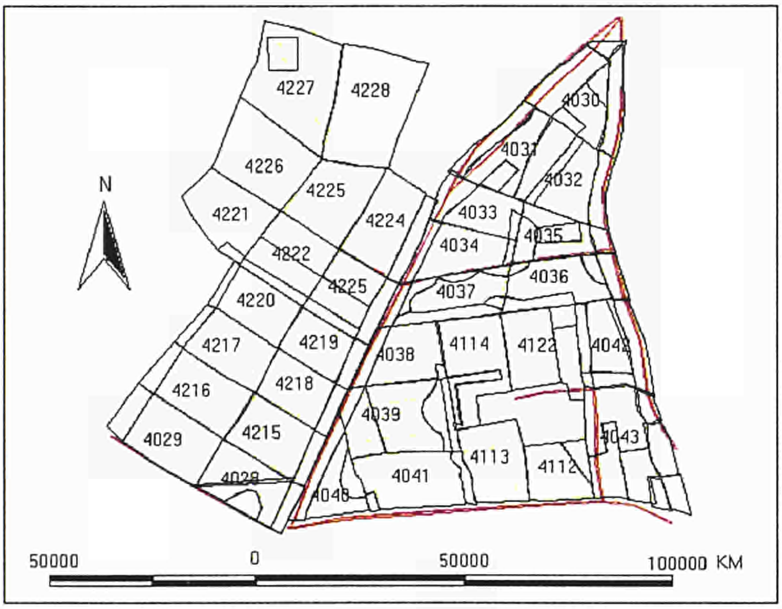

FIGURE 1: Study site

The study site selected for detailed analysis is located in the north-west quadrant of the Kings Forest. (FIGURE 1). It consists of 34 compartments and 95 sub-compartments covering approximately 360 ha. The stands within these compartments have been intensively managed with pruning and thinning operations. Stands of trees of 0 to 70 years and all stages of growth occur. Corsican Pine dominates all of the compartments, with smaller stands of Scots Pine ranging in size of 0.05 to 1 ha. in some sub-compartments.

3. METHODS AND DATA SET

This study uses indices based on radiometric measurements made by remote sensing. A number of mathematical formulas using visible and near-infrared reflectance, called radiometric vegetation indices, have been proposed for relating radiometric measurements in the visible and near-infrared wavelength ranges to the amount of vegetation present. This study applies a commonly used index, the Normalised Difference Vegetation Index (NDVI). The basis for NDVI is the abrupt increase of vegetation reflectance at a wavelength of about 0.7 μm. this increase may be expressed by formula in equation (1).

$$\text{NDVI} = \frac{NIR - R}{NIR + R}$$

(1)

where NIR represents the surface reflectance measured in the near-infrared spectral band and R represents the reflectance in the red spectral band. The visible and near-infrared reflectance may be obtained by remote measurements from a number of satellites such as LANDSAT, SPOT, and the NOAA series, after correction for calibration, variations in solar incidence and atmospheric distortions. In this study, NDVI values were extracted from SPOT 2 HRV 2 image. To analyse the NDVI and the variables affecting vegetation growth, the following two data sets were assembled.

1) Satellite data - SPOT 2 HRV 2 multispectral data for path 33, row 244 on 15th June 1996
2) Secondary data - Forest compartment records from the Forestry Commission.

The SPOT image was used to calculate NDVI using equation 1. The image was atmospherically corrected by using a version of 5S Model. (Tanre et al. 1990). Before calculation of NDVI a geometric correction and a radiometric adjustment were carried out. The geometric correction removes distortions caused by the position and tilt of the spacecraft and by the earth's rotation, resulting in an image of the desired scale and map projection. Although SPOT imagery on computer compatible tape (CCT) has been corrected for earth curvature and rotation, satellite altitude errors still cause significant geometric distortions. The image was geometrically rectified by a first order polynomial nearest neighbour resampling method using ERDAS Imagine version 8.4. The procedure resampled the whole of the image, relocating the original pixels to match the new map base by relocating recognisable geographic features that are common to both the image and the map co-ordinate system. These features are termed ground control points (GCP). Twenty GCPs were selected from each image. The root mean square error (RMS) after correction was less than 1 pixel width. Radiometric adjustment was then carried out, with the 5S model using input data on the meteorological visibility to determine the reflectance values.

The sub-compartment forest base map of the study area provided by the Forestry Commission district office in East Anglia was used as a main source for this study. Thirty-four sub-compartments of Corsican Pine of various ages were selected and the four stand parameters were calculated using yield tables provided. For overlay operations in the GIS, the compartment map of the study site was digitised and converted to raster format in MapInfo. The digital compartment map was registered to the remote sensing images using GCPs for which the co-ordinates had been accurately determined. To analyse the GIS digital compartment map imported to the ArcView format, structural data on tree development were compiled for analysis from management tables supplied by the Forestry commission district office.

4. RESULTS AND DISCUSSION

4.1 Spatial pattern of NDVI in the study site

The NDVI is a quantitative measure, which is related to vegetation vigour. High values of NDVI identify pixels covered by substantial proportions of green vegetation, while low values indicate pixels with bare soil. FIGURE 2 shows the NDVI image of the study site (part of Kings forest pine plantation). It is displayed in greyscale and emphasises differences of NDVI values ranging from a minimum of 0.235 to a maximum of 0.831.

Areas with high NDVI values appear in lighter tones on the image, while low values are in darker tones. According to the different tones, the following three cover types can be identified:

1) Bare land – low NDVI with darker tone.
2) Coniferous forest (mainly pine trees) – moderate NDVI with medium tone.
3) Broadleaf forest -high NDVI with brighter tone

On the basis of different NDVI values it is easy to recognise the following groups: (shown in figure 2)

1) Infant pine plantation, < 8 years, marked * in the image
2) Very young pine plantation, 8 – 18 years, marked A 1 in the image
3) Young pine plantation, 18 – 38 years, marked A2 in the image
4) Mature pine plantation, > 38 years, marked B in the image.

4.2 Description of Structural variables

The correlation between forest stand variables and spectral variables at each compartment in the study site was analysed. From a management point of view the growth of trees may be measured in term of increases in height, diameter, volume or weight. The study selected tree top height, mean diameter, basal area and yield class as stand variables and these values were calculated from Forest Management Tables. (Forestry Commission Booklet 34). Top height is defined as the average total height of the largest trees in the stand (assessed by their diameter of breast height, dbh). For most measurement purposes, the mean tree diameter in a stand is that of mean basal area, also called the quadratic mean dbh. Diameters are measured in centimetres and mean diameter is recorded to the nearest whole centimetre. The basal area of an individual tree is the cross-sectional area in m^2 of the tree at its breast height point. So the basal area of a stand is the sum of the basal area of all the trees in the stand. The rate of tree growth is conventionally defined through yield classes. Yield class is an estimate of the maximum Mean Annual Increment (MAI) tree volume per hectare per year. The average volume increment from planting to any point in time shown by MAI. The curve reaches a maximum where it crosses the Current Annual Increment (CAI) curve, which represents an annual volume increment at any point in time. This point defines the maximum average rate of volume increment, which a particular stand can achieve, and is used to indicate yield class. For example a stand with a maximum MAI $14m^3$ /ha has a yield class of 14.

The distribution pattern of the structural variables is shown in FIGURE 3. It shows digitised compartment polygon surfaces for top tree height (3a), mean diameter (3c), basal area (3d) and yield class (3b) in the study site, derived from management tables. The regional distributions of three of the surfaces (3a, 3c and 3d) follow a similar pattern. Approximately 75% of the compartments cover class categories in the middle of the range. For example, top tree height ranges from 18.0 to 22.7 m, the mean diameter ranges from 12.6 to 32.1 cm and basal area surface ranges from 27.9 33.2 m^2/ha^{-1}. In contrast, yield class distribution (3b) is more skewed with 90% of the compartments in the higher-class 13-18 m^3/ha categories.

Measurements of standing trees such as top tree height, mean diameter and basal area, are necessary for several management purposes such as inventory, planning, and the control of resources. Yield class is an indicator of a tree volume and has become a vital tool in forest management, especially for production forecasting. The Forestry Commission of Britain has prepared these yield classes for all the major commercial species in Britain. Analysis of these data showed that most of these variables except yield class were intercorrelated. (TABLE 1).

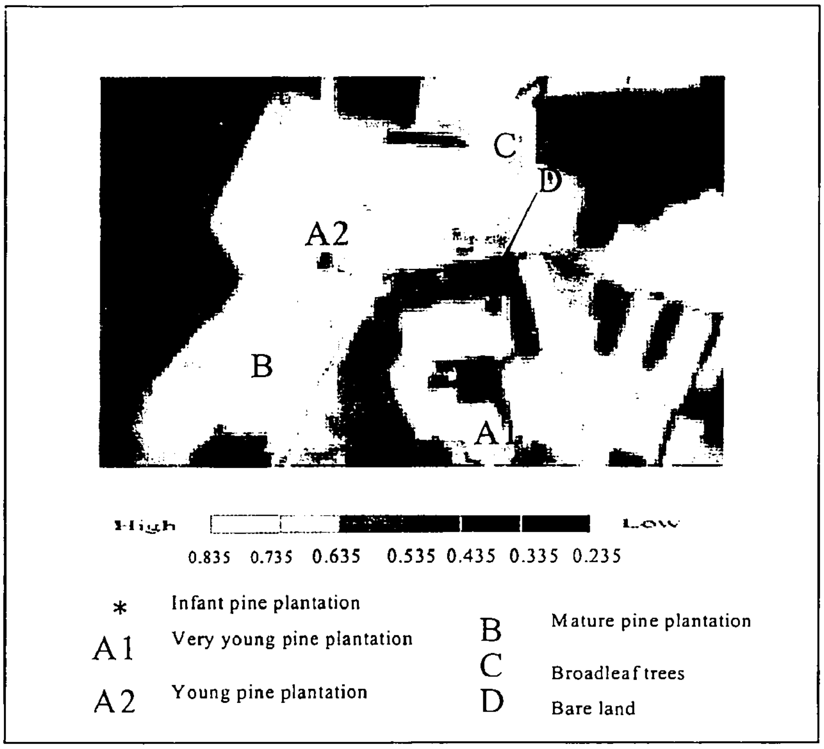

FIGURE 2: NDVI image of the study area – 15 June 1996

Mean diameter and basal area both increase with the tree height as they are related to tree growth. Yield class decreases with basal area due to the management practice of thinning. This practice involves the periodic removal of a number of trees leading to a negative correlation between these parameters. Mean diameter and tree height however, showed a weak positive correlation with yield class.

4.3 Relationship between NDVI and structural variables

Recent studies have shown that remotely sensed data can be related to several forest site parameters including Leaf Area, (Gong et al. 1992; Baoxin et al. 2000) and canopy cover (Carlson and Ripley 1997). These studies were based on Thematic Mapper Simulator data collected from airborne sensors and demonstrated that remotely sensed data exhibits a good correlation with Leaf Area Index and canopy cover. The work described in this paper used SPOT 2 HRV 2 data with other structural parameters that are more closely related to forest management, such as top height, mean diameter, basal area and yield class.

TABLE 1: Correlation between forest stand parameters

		MD	TH	BA	YC
Correlation coefficients	MD	1.000	.983	.854	.068
	TH	.983	1.000	.786	.114
	BA	.854	.786	1.000	-.032
	YC	.068	.114	-.032	1.000

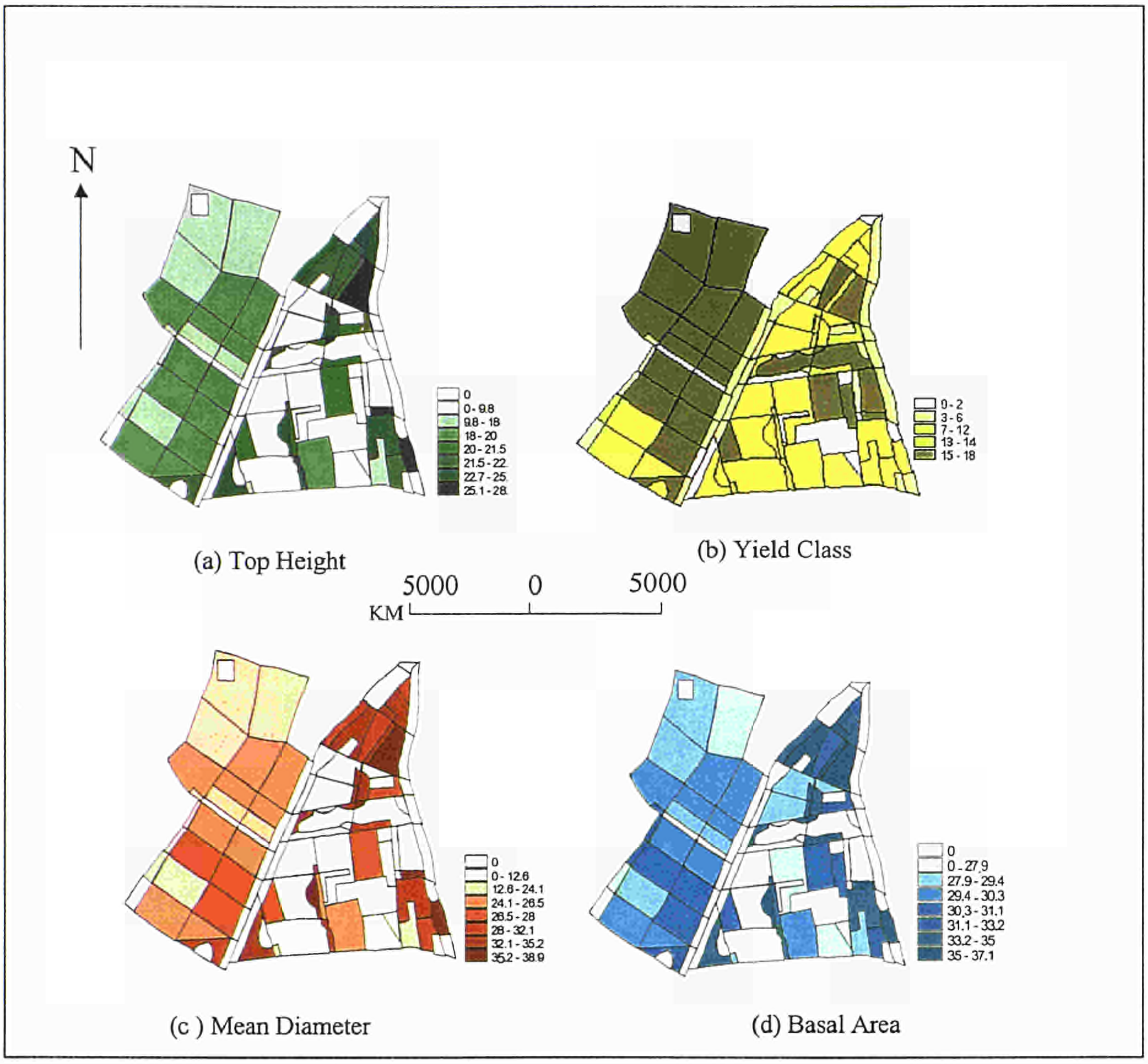

FIGURE 3: Distribution maps of structural variables in the study site

The result of this study shows there was a positive high correlation between NDVI and tree top height (4a) and mean diameter (4b) with correlation coefficients of 0.73 and 0.76 respectively, which are significant at the 95% confident level. The patterns of relationship are shown in the scatter diagrams. In the lowest height and diameter classes, NDVI increases rapidly with top height and mean diameter. At this stage small deciduous trees and grass cover dominates the canopy and the expansion of leaf area of the stand is largely due to the high proportion of background influences. NDVI increases rapidly from 0.431 to 0.601 because the red reflectance is inversely related to leaf area while the near-infrared reflectance is positively related to leaf area. At the next stage (15-25 top height range and 20-35 mean diameter range) the increase of NDVI with structural variables shows a different relationship. According to the Forestry Commission, the tree top height of the stand increases to 15-25 meters by the age of 20-25 years, at which stage the trees are thinned. When the tree canopy is thinned, some areas without vegetation will be exposed. The two solitary points with very low NDVI in the middle of the height and area ranges are probably compartments that have very recently been thinned. Herwitz, (1990) states that when the thinning treatment affects over 28% of the canopy, the LAI

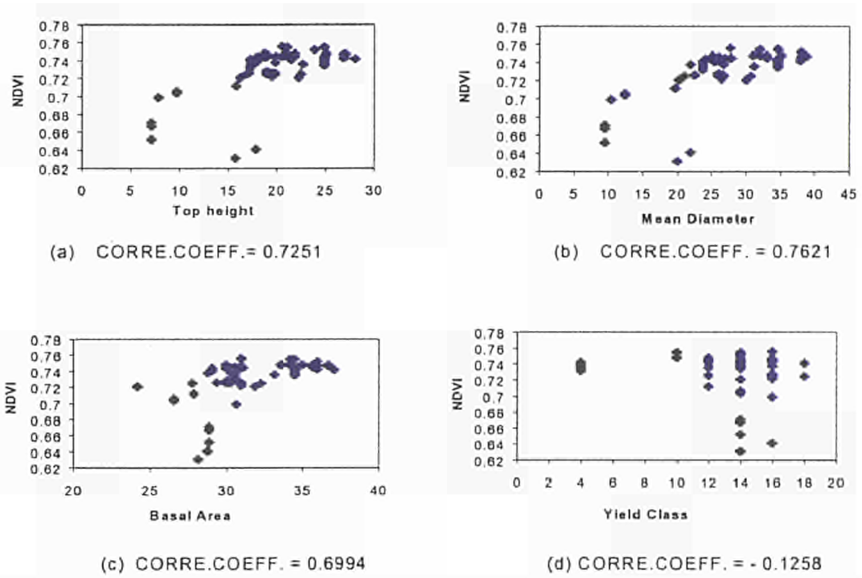

FIGURE 4: Relationship between NDVI and structural variables in Corsican Pine, with correlation coefficients, r.

tends to be permanently reduced and the pre-thinned LAI of the forest plantation do not become re-established. In the later stages, when the stand is regularly thinned, there is little evidence of crown expansion and leaf area tends to be stable. The result of this situation is that the increase of NDVI with height and diameter is relatively slow. Finally, during the mature stage, when the thinning treatment has stopped, the growth of the remaining trees fills in any gaps in the canopy, leading to an increase in near-infrared reflectance. At the same time, due to the influence of background effects, reflection from the red portion also slightly increases. Due to felling operation in the latter stage few mature trees are left in the plantation. The distance between crowns and inter-crown shadowing tends to increase. The increased shadowing would be expected to reduce reflectance, particularly in visible band, which is sensitive to shadows. But here it has shown that a slight increase of red reflectance and decrease of near-infrared reflectance occurs. A possible explanation is that the woody twigs and branches supporting the pine foliage become exposed to incoming radiation, increasing red reflectance and decreasing near infrared reflectance, (Campbell 1996). NDVI change with structural variables is very small at this stage.

The correlation between NDVI and basal area presents a different picture, with a lower correlation coefficient of 0.70 (4c). This relationship is statistically slightly less significant than for tree top height and mean diameter. The NDVI data are the same for figures 4 a-d, so the difference in pattern in figure 4c must be related to the effect of thinning on basal area. Basal area is proportional to the square of tree diameter and to the number of trees per unit area. The effect of thinning is to reduce drastically the number of trees while maintaining the mean diameter. All but three or four of the youngest compartments in figure 4 have already been thinned at least once, so it appears in figure 4c as though these young compartments have been shifted to the right relative to their position in 4b.

No correlation was found between NDVI and yield class (4b), and it is suggested that in this situation, yield is not a function of vegetation amount. The lack of correlation with yield class may be an effect of its calculation. Yield class is related to the top height and age of the stand, but individual stands will not always follow these growth rates. A stand may grow faster than its yield class suggest for part of its life, and at other times it may grow slower. On the other hand fertilising the stand will increase the growth rate. In both of these situations, using yield class as a forest parameter may not very helpful. It is adequate for most management purposes, but may not be a good predictor of future forest growth.

5. Summary and conclusion

The present study consists of two components:
1) Spatial changes were identified.
2) Correlation between NDVI and selected forest stand parameters were analysed.

It has shown that NDVI change spatially with differences of surface vegetation cover. NDVI values range from a low of 0.235 on bare land to a high of 0.831 in broadleaf hardwood areas. In the Pine plantation, moderate NDVI values (0.431-0.779) occur, appearing in medium tones on the image. The pattern may vary with the background effect and thinning treatments. However, further investigations are needed to clearly identify the changes of NDVI with these variations.

With the exception of yield class, the regression analysis for three stand parameters (top tree height, mean diameters and basal area) with NDVI has shown high positive correlations (r= 0.73, 0.76 and 0.70 respectively). The correlation coefficients for yield class with NDVI were very low. These results give an indication of the value of SPOT 2 HRV 2 data for estimating forest stand parameters.

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References

Bannari, A.D., Morin, D., Bonn, F. 1995. A review of vegetation indices. Remote Sens. Review, 13: 95-120.

Baoxin, H., Inannen, K., Miller, J.R. 2000. Retrieval of Leaf Area Index and canopy closure from CASI data over the Boreas flux tower sites. Remote Sens. Environ. 74: 255-274

Campbell, J.B 1996. Introduction to remote sensing Ch. 13. The Guildford Press

Carlson, T.N. and Ripley, D.A. 1997. On the relation between NDVI, fractional vegetation cover and Leaf Area Index. Remote Sens. Environ. 62: 241-252

Congalton, R.G., Green, K., Teply, J. 1993. Mapping old growth forest and national forest and park land in the Pacific Northwest from remotely sensed data. Photogramm. Eng. And Remote Sens. 59:529-535.

DeWulf, R.R., Pierce, L.L , Peterson, D.L., Running, S.W. 1990. Remote sensing of coniferous forest leaf area index. Int. J. Remote Sens. 11(1): 95-111

Gong, P., Pu, R., Miller, J. 1992. Correlating leaf area index of ponderosa pine with hyper spectral CASI data. Canadian Journal of remote sens. 18: 275-182.

Hall,F.G., Botkin, D.B., Strebel, D.E, Woods, K.D., Goetz, S.J. 1991. Large- Scale patterns of forest succession as determined by remote sensing, Ecology 72: 628-640.

Herwitz, S.R., Peterson, D.L., Eastman, J.R. 1990. Thematic Mapper detection of changes in the leaf area of closed canopy Pine plantations in central Massachusetts. Remote Sens. Environ. 29: 405-428

Knipling, E.B. 1970. Physical and Physiological basis for the reflectance of visible and near infrared radiation from vegetation. Remote Sens. Environ. 1: 155-159.

Morrison, P.H. 1990. Ancient Forest on the Olympic National Forest. The Wilderness Society: Washington DC.

Morrison, P.H., Kloepfer, D., Leversee, D.A., Socha, C.M., Ferber, D.L. 1991. Ancient Forest in the Pacific Northwest: Analysis and Maps of twelve National Forests, The Wilderness Society: Washington DC.

Running, S.W. and Coughlan, J.C. 1988. A general model of forest ecosystem processes for regional applications. 1. Hydrological balance, canopy gas exchange, and primary production processes. Ecological Modelling, 42: 125-154.

Sader, S.A. and Winne, J.C. 1992. RGB-NDVI colour composites for visualizing forest change dynamics. Int.J. Remote Sens. 13: 3055-3607.

Stenback, J.M. and Congalton, R.G. 1990. Using thematic Mapper imagery to examine forest understory. Photogramm. Eng. Remote Sens. 56(9): 1285-1290

Tanré, D., Deroo, C., Duhaut, P., Herman, P.M., Morcrette, J.J., Perbos, J., Deschamps, P.Y. 1990. Technical note, "Description of computer code to simulation satellite signal in the solar spectrum; the 5S code.2".sw Int. J. Remote Sensing. 11: 659-668.

MEDITERRANEAN FORESTRY: DATA MODELING RESEARCH NEEDS

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ABSTRACT

Mediterranean forest ecosystems are generally characterized by abundant biological diversity and by a fragility that derives from a harsh climate and difficult socio-economic conditions. The consequent complexity of Mediterranean forest ecosystem management points to the urgency of both promoting interdisciplinary research and organizing Mediterranean natural resources data. Research in Ecology, Economics and other pertinent subject areas is expanding at an ever-increasing speed. Yet this expansion of research may lead to a waste of resources if data is not modeled such that information is adequately organized and distributed. This paper presents preliminary results from research aiming at modeling Mediterranean natural resources data. Specific challenges to be addressed include the linkage of plant, animal and economic data and the integration of spatial and aspatial data. A cork oak ecosystem extending over about 20x10^3 ha in Southern Portugal is used as a case study for illustrating Mediterranean forestry data modeling research needs.

Keywords: Mediterranean forestry, management information system, data modeling, Mediterranean ecosystem management

1. Introduction

Forest owners, managers and policy-makers are asked today to develop, respectively, plans and policies that can both produce or promote traditional Mediterranean economic goods (e.g. timber and cork) and sustain the forest ecological base. Yet the specificity of Mediterranean ecological characteristics, the stressful socioeconomic conditions and a history of forest resources over-exploitation presents a challenge to researchers, landworkers, landowners, policy-makers and, generally, to all citizens concerned with the management of Mediterranean forest ecosystems. We are becoming increasingly aware of the impacts of extractive activities on the Mediterranean natural systems that provide habitat for wildlife, hydrological filtering, erosion control and other ecosystem services. These ecological values must be safeguarded even as we extract the tangible economic products from these natural systems (Borges 2001).

Several studies stress specific Mediterranean forest ecosystem management issues. Yet poor or insufficient data, production functions and growth and yield models are still a major bottleneck for any sound Mediterranean forestry decision analysis exercise. Moreover, lack of information in a usable form and inefficient and/or untimely transfer of data to appropriate users have been barriers to utilizing the best available knowledge in Mediterranean ecosystem management and to identifying priorities for information generation through research. Little experience in linking state-of-the-art multifunctional management models and non-market valuation economic methods makes it difficult to address the complexity of the resources facets and interactions within the framework of decision analysis and policy-making. Nevertheless, literature related to other forest ecosystems demonstrates the potential of an approach to integrate data modeling, growth modeling and management and economic modeling within the framework of a computational interface such as a decision support system (Borges 2001).

2. The development of an Information System for Mediterranean Forest Ecosystem Management

The variety of Mediterranean data sources and the lack of standards for data acquisition and storage constrain efficient generation of information and its timely sharing among ecosystem researchers, managers and the public. Adequate information systems have not been designed for Mediterranean forest ecosystem management and represent a great challenge for information specialists. Several problems are faced by the users of Mediterranean resources information systems. The variety of researchers and their diverse objectives make the integration of existing use-specific databases especially difficult. In addition to the diversity of sub-disciplines in Mediterranean resources management, a diversity of ownerships is involved. The quality, adequacy, and design of the databases maintained by different ownerships varies considerably. Because standards do not exist or are not widely accepted, data from different ownerships are frequently incompatible and difficult to reconcile (Borges 2001).

To integrate data resources, a detailed and complete understanding of the relationships that exist between data elements within a database must be obtained, and formalized, so that the information system development may be compatible, consistent, reliable, and able to answer the complex questions that cannot be anticipated but are certain to arise. So, the conceptual design process is concerned with determining who needs what data, and how those real world objects are related to each other (Pelkki 1992).

System analysis is crucial for the development of an adequate information system. It encompasses both process modelling and data modelling. Process modelling involves the identification of external entities that exchange data with the system, of data flows, of processes and of archives within the system (Robinson 1995). Data modelling encompasses the development of an entity relationship model as described in Besh (1999), Chen (1996), Date (1995), McFadden (1993) and Pelkki (1994). The development of the prototype Mediterranean forestry information system presented in this paper took advantage of previous experience in building forest ecosystems information systems (e.g. Miragaia et al. 1996; Miragaia et al. 1998a and 1998b; Miragaia et al. 1999 and Ribeiro et al. 2000). Key components of the data model — entities, attributes and relationships – were identified. An entity corresponds to the basic units of the relational model and attributes correspond to the entities characteristics. The relationships are the logical links between two entities and can be of three different kinds: 1-1, 1-N and M-N (Codd 1990).

3. Model implementation

The software Microsoft Access® Database Management System was selected for physical implementation of the prototype Mediterranean Informaton System. Each entity in the conceptual model corresponds to one table (Miragaia e Borges 1998). The entity's attributes were defined as table's fields. A primary key (sets of one or more fields that define univocally one occurrence – there aren't two occurrences with the same primary key) was defined for each table. Fields' size and type (e.g. integer, single and text) were specified so that data storage errors and waste of storage space were avoided. The implementation of relationships between tables involved the definition of the relationship type (one-to-one, one-to-many, and many-to-many). Preliminary research led to the identification of 39 main entities and 88 secondary entities.

Prototype interfaces for data acquisition and for information presentation (Figures 1 and 2) are being tested in the framework of ongoing, research and outreach projects. Its design considered simplicity and user friendliness criteria. Validations rules for specific data were also implement through the interfaces.

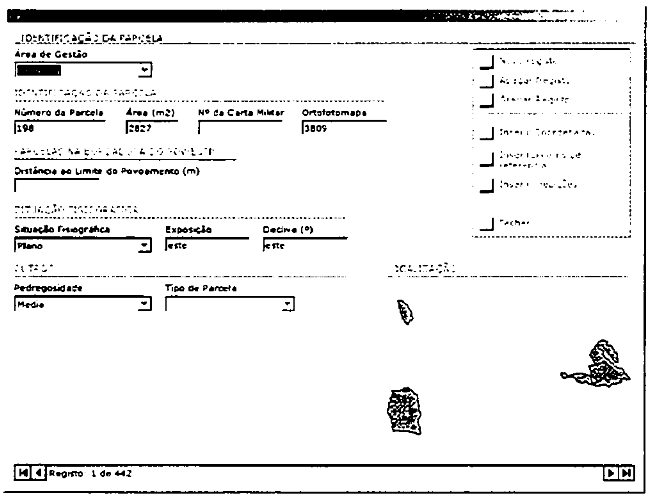

FIGURE 1. Example of an interface for data acquisition

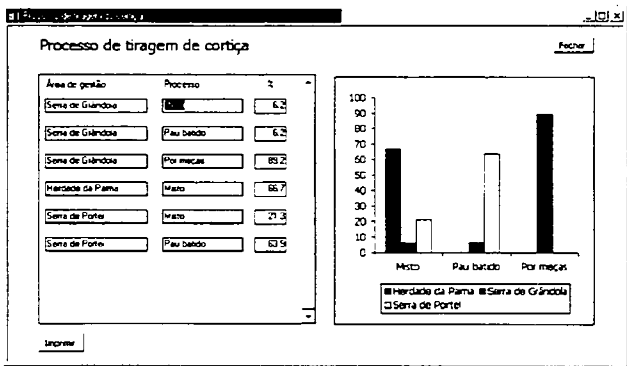

FIGURE 2. Example of an interface for presenting information

4. Discussion And Results

This paper presents preliminary results from research aiming at modeling Mediterranean natural resources data. The variety of researchers and their diverse objectives make the integration of existing use-specific databases especially difficult. The quality, adequacy, and design of the database are of extremely importance for all the decision makers.

The information systems allow the standardization of the data and minimization of data acquisition errors. This data model and its prototype implementation is currently being tested with data from Mediterranean ecosystems (e.g. 442 traditional forest inventory plots, 674 wildlife inventory plots, 142 socio-economic inquires). Further research will aim at a physical implementation within a client/server environment and at the revaluation of its current structure for enhanced integration of different data sources. Finally, future development will encompass the testing of visualization tools to present combined information related to forest resources , wildlife resources and local and regional socio-economics.

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References

Besh, D., 1999, SQL Server 7 Database Design, New Riders Publishing, 550p.

Borges, J. G., 2001. MEDECO Project Proposal – Mediterranean forest ecosystem management: an integrated stand-to-landscape approach to ecological, economic and sustainability.

Chen, P., 1976, The entity-relationship model – Toward a unified view of data" ACM Trans. Database Syst., Vol.1, n.'°1, March, 9-36 p.

Codd, E. F., 1990, The Relational Model for Database Management. Addison-Wesley Publishing Company, 836p.

Date, C. J., 1995, An Introduction to Database Systems, New York, Addison-Wesley Publishing Company, Inc.

McFaden, F. R., Hoffen, J. A., 1995, Database Management. The Benjamin/Cummins Publishing Company, Inc. Menlo Park, ca.

Miragaia, C., Borges J., Falcão, A. and Tomé, M., 1998a, "inFlor – a management information system of forest resources". *In* Modeling the Growth of Tree Plantations and Agroforestry Systems in South and East Africa, p131-142. Edited by T. Pukkala and K. Eerikainen, University of Joensuu, Faculty of Forestry Research Notes 80.

Miragaia, C., J. G. Borges e M. Tomé, 1998b, "inFlor, um sistema de informação em recursos florestais. Aplicação em gestão na Mata Nacional de Leiria". Revista Florestal XII(1/2), 51-56.

Miragaia, C., J. G. Borges, F. A. Rodrigues e L. C. Rodriguez, 1999, "Uma aplicação do sistema inFlor na gestão de dados florestais". Circular Técnica IPEF 190, IPEF-ESALQ, Universidade de S. Paulo, Brasil, 6 p.

Miragaia, C., N. Teles, L. Silva, T. Domingos e J. G. Borges, 1996, "Desenvolvimento de um sistema de informação para o apoio à decisão em recursos naturais". Revista Florestal IX(3), 46-50.

Pelkki, M.H. and Rose, D., 1994, Understanding Relational Database Planning and Design. Compiler 12(2), p27-31.

Ribeiro, R., Miragaia, C., Borges J., 2000, "A prototype management information system for plantation forests in eastern and southern Africa" *In* Establishment and management of tree plantations in South and East Africa, p121-131. Edited by T. Pukkala and K. Eerikainen ., University of Joensuu, Faculty of Forestry Research Notes 120.

Robinson, B., M. Prior 1995. Systems analysis techniques. International Thomson Publishing, 276 p.

Landscape evenness measures: their nature and mutual relatedness

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Abstract

Several evenness measures have been proposed for quantifying the distribution of abundance among land cover classes within a landscape, but none seems to be generally preferred. Since these measures share a common objective, they may be expected to be intercorrelated. In this paper, seven standard measures of evenness were calculated for 20 CORINE land cover maps of Italian Regions. Principal component analysis was used to identify the primary aspects of landscape organization being characterized by these seven indices. The first two principal components explained 98% of total variance. A comparison of the first two principal components with the analyzed measures of evenness provides insight into what aspects of landscape organization they are expressing. While the first principal component is most sensitive to the relative abundances of rare land cover classes, the second principal component is clearly associated to changes in the abundance of the dominant land cover class.

Keywords: Correlation, Evenness, Lorenz ordering, Principal component analysis

1. Introduction

Landscape spatial features are essential factors in forest ecosystem functioning, so their assessment is recognized as a relevant issue for both forest ecology and management planning (Ciancio et al. 1999). Within this framework, in the past two decades, as the influence of global change became more prominent, ecological research has been conducted at increasingly larger spatial scales (Gustafson 1998). Since terrestrial landscapes generally consist of mosaics of different ecosystems, as ecological analyses move from ecosystem to landscape scale, it becomes necessary to understand the ecological functions of large spatially heterogeneous areas. This is expecially true for the forested landscapes in the Mediterraenan countries (e.g. Ricotta et al. 1999).

Landscape ecology explicitly assumes that diversity and spatial arrangement of ecosystem mosaics has ecological implications and tries to understand the interactions between diversity and structure of large spatially heterogeneous areas and its ecological functions (Forman and Godron 1986; Forman 1995).

The spatial variability of ecosystem mosaics is typically represented by categorical (i.e., thematic) maps that quantize this variability by identifying patches that are relatively homogeneous and that exhibit a relatively abrupt transition to adjacent areas (Gustafson 1998). As a consequence, a large number of indices has been developed to quantify different aspects of categorical maps as a surrogate of landscape mosaics and correlate them to ecological processes (Baker and Cai 1992; MacGarigal and Marks 1995; Riitters et al. 1995).

In particular, landscape evenness measures the degree to which one or few land cover classes (LCCs) predominate the landscape in terms of relative abundance without regard to LCC names or labels (Forman 1995). Maximum evenness (1.0) occurs for an equiprobable distribution of LCCs across the landscape, and the more that relative abundances of LCCs differ the lower the evenness is. The concept of evenness is closely related to that of landscape diversity. It is generally agreed that diversity measures should combine two components: LCC richness (the number N of LCCs) and evenness. High LCC richness and high evenness jointly imply high diversity. Further, although landscape evenness is not a measure of landscape structure, evenness measures reflect landscape spatial dependence to a certain degree. For example, a strongly dominant LCC would have large patches even if LCCs were assigned to pixels at random from a fixed relative abundance distribution. The paradigmatic example of this behavior is percolation theory (Loehle et al. 1996; Milne et al. 1996).

Several evenness indices have been proposed (Taillie 1979; Smith and Wilson 1996). However, none seems to be generally preferred. In addition, while the ecological and statistical properties of most indices of landscape diversity and structure are well known, little attention has been devoted to the understanding of the properties of measures of landscape evenness. Summarizing a large data set into a few numbers generally results in some loss of information. Therefore, some would argue that evenness indices conceal more than they reveal (Rousseau et al. 1999). However, land cover data are often multivariate of high dimension so there is a need for summarization. Since different evenness measures are attempting to quantify the same aspect of LCC relative abundance distribution, they can be expected to have a high degree of intercorrelation. In this paper, we analyze the mutual relatedness of seven standard evenness measures. Ideally, there is a small set of measures that characterize different aspects of the relative abundance distribution of LCCs without being mutually redundant (Riitters et al. 1995; Basak et al. 2000). Therefore, the purpose of this study was to determine (i) the number of independent aspects of LCC distribution that are summarized by these seven evenness measures, and (ii) the indices which best quantify these independent aspects of LCC distribution.

2. Requirements for an ecologically meaningful evenness measure

Many authors (Taillie 1979; Routledge 1983; Smith and Wilson 1996) have proposed basic criteria that an index should satisfy in order to qualify as a measure of evenness. An ecologically acceptable measure of evenness should be reasonably simple to compute and applicable to any landscape independently of the underlying LCC distribution (Alatalo 1981; Lande 1996). Furthermore, it should be well defined mathematically in a way to be really useful in ecological applications. The foremost requirement for a meaningful evenness index is that it must be independent of the number of LCC (Smith and Wilson 1996). This requirement is based on the assumption that landscape diversity can be partitioned into two components, LCC richness and evenness. If the separation is incomplete, so that evenness is affected by the number of LCCs, then differences in evenness values could result from differences in the LCC count rather than any fundamental difference in landscape organization (Sheldon 1969).

As a precise formulation for this notion of independence of LCC richness, Hill (1973) proposed that replication should not change the value of landscape evenness. Consider a landscape composed of N LCCs characterized by the relative abundance vector $P = (p_1, p_2, ..., p_N)$ such that such that $0 \leq p_i \leq 1$ and $\sum_{i=1}^{N} p_i = 1$. It seems reasonable that replicating the LCC sequence n-times (and renormalizing) should multiply richness by n but leave evenness unchanged. Notice that this replication property is part of Taillie's (1979) more general requirement that an evenness index maintains the natural ordering introduced by the Lorenz curves used by economists to compare wealth distributions.

The Lorenz curve is obtained by plotting the cumulative LCC relative abundances as abscissa against corresponding cumulative proportions of LCCs as ordinates. Arrange the components of the LCC relative abundance vector P of a given landscape in descending order so that the ranked abundance vector $P^{\#} = (p_1^{\#}, p_2^{\#}, ..., p_N^{\#})$ is obtained, where $p_1^{\#} \geq p_2^{\#} \geq ... \geq p_N^{\#}$. The Lorenz curve is then defined as the polygonal path joining the successive points: $\pi_0 = (0, 0)$, $\pi_1 = (p_1^{\#}, 1/N)$, $\pi_2 = (p_1^{\#} + p_2^{\#}, 2/N)$, ..., $\pi_N = (p_1^{\#} + p_2^{\#} + ... + p_N^{\#}, N/N) \equiv (1, 1)$ (Figure 1).

The resulting diagram is similar to the intrinsic diversity profile proposed by Patil and Taillie (1979, 1982) for defining the concept of intrinsic diversity order: both use as abscissa the cumulative LCC relative abundances, however, the intrinsic diversity profile uses as ordinate the cumulative number of LCCs, whereas the Lorenz curve uses as ordinate the cumulative proportion of LCCs. Patil and Taillie (1979, 1982) defined landscape A to be intrinsically more diverse than landscape B without reference to indices, provided B leads to A by a finite sequence of forward transfers of abundance (for mathematical details, see Patil and Taillie 1979, 1982). Following this definition, the hypothetical landscape A is intrinsically more diverse than landscape B if and only if landscape A has its intrinsic diversity profile everywhere above that of landscape B. Notice that the ordering is only partial in that two landscapes need not necessarily be intrinsically comparable. In this latter case, the intrinsic diversity profiles of both landscapes cross one another. Similarly, landscape A is intrinsically more even than landscape B if and only if landscape A has its Lorenz curve everywhere above that of landscape B. Consequently, a measure of evenness E that is invariant under LCC replication maintains the Lorenz ordering provided that E is consistent with the intrinsic diversity ordering when restricted to landscapes with the same number of LCCs (Taillie 1979). For instance, when diversity comparisons are restricted to landscapes with the same number of LCCs, since there is no fundamental difference between diversity and evenness when LCC richness is held constant, the intrinsic diversity ordering is identical to the corresponding Lorenz ordering.

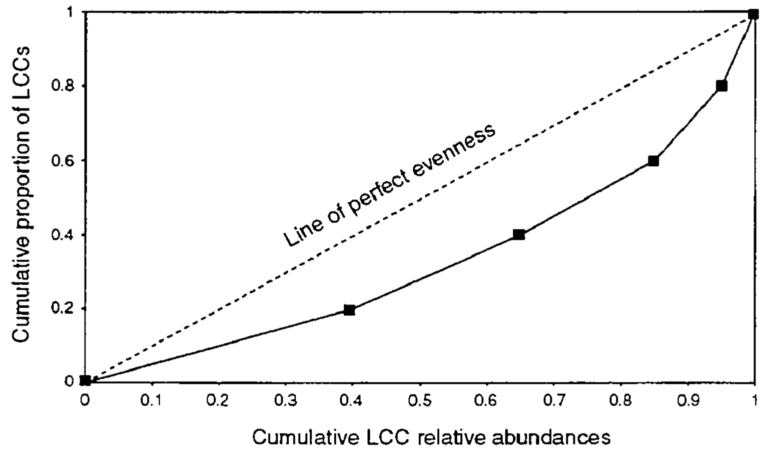

FIGURE 1: Lorenz curve for an artificial landscape composed of 5 LCCs with relative abundances 0.40, 0.25, 0.20, 0.10, 0.05. Dotted line represents the Lorenz curve for a perfect even landscape, i.e., for a landscape where $p_i = p_j$ for all LCC pairs i, j = 1, 2, ..., N.

3. Index selection

We consider seven standard evenness indices that are consistent with the Lorenz ordering. These indices include:

The index of Bulla (1994):

$$O = \sum_{i=1}^{N} \min(p_i, 1/N) \qquad (1)$$

The Gini index, i.e., twice the area under the Lorenz curve (Taillie 1979):

$$I = \left(2\sum_{i=1}^{N} i^{\#} p_i^{\#} - 1\right) \Big/ N \qquad (2)$$

where $i^{\#}$ denotes the rank of the i-th LCC within the ranked abundance vector $P^{\#}$. Notice that I is related to Camargo's (1992) dominance index d' by the simple relation I = 1 – d', where

$$d' = \sum_{i=1}^{N} \sum_{j \geq i}^{N} \left| p_i^{\#} - p_j^{\#} \right| \Big/ N$$

and $p_i^{\#}$ and $p_j^{\#}$ are the ranked relative abundances of the i-th and j-th LCC, respectively so that, $i^{\#} > j^{\#}$.

Two indices proposed by Taillie (1979):

GM/AM (3)

and

HM/AM (4)

where AM, GM and HM are the algebraic mean, the geometric mean and the harmonic mean of the LCC abundances, respectively.

Three moments of Hill's (1973) parametric evenness family

$$E_{\alpha.0} = N^{-1}\left(\sum_{i=1}^{N} p_i^{\alpha}\right)^{\frac{1}{1-\alpha}}$$

where α is a parameter that ranges between 0 and ∞ (Taillie 1979; Ricotta and Avena 2000):

$$E_{1,0} = (\exp H)N^{-1} \quad (5)$$

where H is Shannon's entropy $-\sum_{i=1}^{N} p_i \log p_i$

$$E_{2,0} = D^{-1}N^{-1} \quad (6)$$

where D is Simpson's dominance index $\sum_{i=1}^{S} p_i^2$, and

$$E_{\infty,0} = p_{max}^{-1}N^{-1} \quad (7)$$

where p_{max} is the proportional abundance of the most frequent LCC.

4. Methods

Twenty land cover maps in raster format of the Italian Regions with a grain size of 50m were selected for analysis. Each map cell is classified into one of the possible CORINE 3rd level attribute classes. CORINE land cover is a project of the Commission of the European Union, which aims to map land use and land cover consistently across all member states (Fuller and Brown 1996). CORINE maps land cover into 44 classes, in vector format, at 1: 100.000 scale, with a minimum mappable unit of 25 ha (Anon. 1992). The methodology consists of the computer-assisted visual interpretation of satellite images with the simultaneous consultation of ancillary data and manual digitizing of the resultant linework.

The 44 land LCCs are grouped in a 3-level hierarchy. The main level categories are: artificial surfaces (cities, etc.), agricultural areas, forest and semi-natural areas, wetlands and water bodies. Each country can add supplementary 4th and 5th hierarchical levels, according to its special conditions and priorities, but the first three levels are identical for all countries. First, for the selected maps, the relative abundance of each CORINE 3rd level LCC was determined. Next, based on the corresponding LCC relative abundance vectors π, the evenness indices O, I, GM/AM, HM/AM, $E_{1,0}$, $E_{2,0}$ and $E_{\infty,0}$ were computed.

5. Results

Simple summary statistics for the selected evenness measures are shown in Table 1. The correlation coefficients of all pairs among the 7 measures are displayed in the triangular matrix of Table 2.

TABLE 1: Summary statistics for the selected evenness measures. Std. Dev. = standard deviation; CV = coefficient of variation.

	Mean	Std. Dev.	CV
O	0.560	0.106	0.189
I	0.497	0.084	0.169
GM/AM	0.621	0.113	0.182
HM/AM	0.434	0.102	0.235
$E_{1,0}$	0.634	0.117	0.185
$E_{2,0}$	0.476	0.123	0.258
$E_{\infty,0}$	0.280	0.087	0.311

Peet (1974) and Magurran (1988) distinguished two groups of diversity and evenness indices. Type I indices are most sensitive to the relative abundances of rare LCCs, while Type II indices are most affected by changes in the abundance of the dominant LCC. Within this framework, in Table 2, $E_{\infty,0}$ is the only measure that is clearly related to the abundance of the commonest LCC. As a consequence, it generally shows lower pairwise coefficients of correlation with the other (Type I) measures of evenness.

TABLE 2: Pairwise correlation coefficients among the selected evenness measures (n = 20).

	O	I	GM/AM	HM/AM	$E_{1,0}$	$E_{2,0}$	$E_{\infty,0}$
O	1.000	0.963	0.982	0.922	0.960	0.847	0.604
I		1.000	0.985	0.930	0.994	0.949	0.776
GM/AM			1.000	0.964	0.977	0.892	0.678
HM/AM				1.000	0.901	0.812	0.592
$E_{1,0}$					1.000	0.958	0.786
$E_{2,0}$						1.000	0.916
$E_{\infty,0}$							1.000

The intrinsic dimensionality of the selected evenness measures was further assessed using standardized principal component analysis (PCA). The data were processed using the Syn-Tax 5.02 package (Podani 1993). PCA undertakes a linear transformation of a set of numerical variables to create a new set of variables (called principal components or factors) that are uncorrelated and are ordered in terms of the amount of variance explained in the original data. Given a data set with n variables, n principal components can be computed. With unstandardized PCA, each principal component is a linear combination of the original variables, with coefficients equal to the eigenvectors of the variance/covariance matrix. With standardized PCA, the eigenvectors are computed from the correlation matrix and the result is identical to standardizing all values (by subtracting the mean and dividing by the standard deviation) and computing the unstandardized principal components of the results. The eigenvectors are customarily taken with unit length and the sum of the variance in all the components is equal to the total variance present in the original dataset.
The component scores of each evenness measure (i.e., correlation with axes) for the first two principal components are shown in Figure 2. These two components together explained 98.33% of total variance, the eigenvalues being 6.237 and 0.646 (89.10% and 9.23%, respectively).

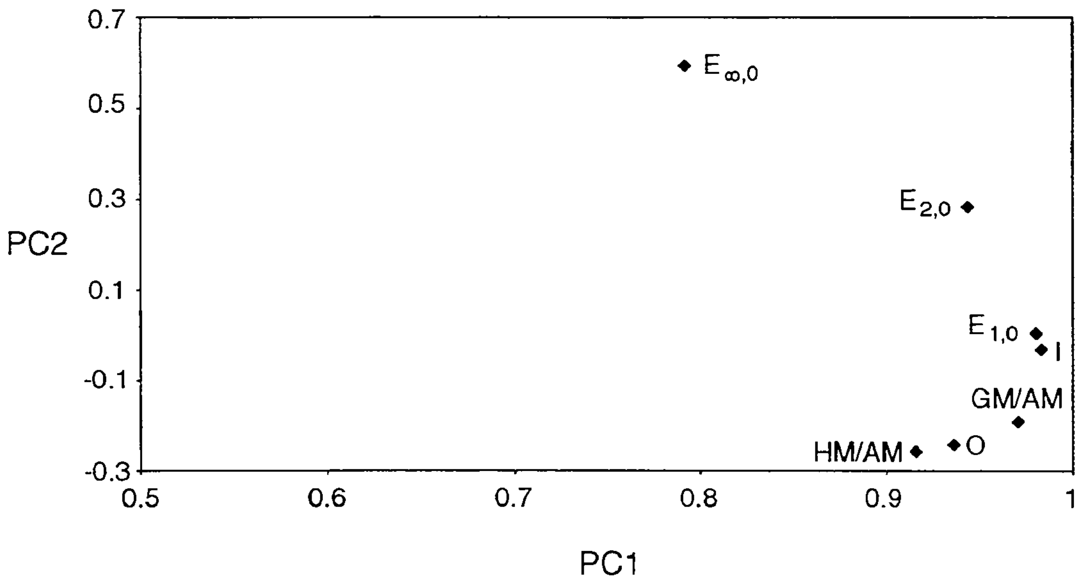

FIGURE 2: Principal components ordination of evenness measures on the first two axes.

There is a rule of thumb suggesting that those principal components are retained in standardized PCA whose associated eigenvalues are greater than one. In essence this is like saying that, unless a factor extracts at least as much as the equivalent of one original variable, we drop it. The first principal component met this criterion, and the second was retained because it appeared to be uniquely and strongly associated with $E_{\infty,0}$ (see Figure 2) confirming the different behavior of this Type II index with respect to all others. In other words, due to the very high redundancy between the selected evenness measures, the original data set may be summarized in a simpler way by the first two principal components.

6. Discussion

To facilitate comparisons among different landscapes, it is worth considering a choice of single evenness measures that could be used as surrogates of the first two principal components (Riitters et al. 1995). This is a somewhat arbitrary decision, but there are some guidelines that may facilitate the choice. A first simple rule is to choose the measures with the highest factor loading on each principal component.

Due to the high redundancy among the analyzed indices, the factor loadings of each measure of evenness on the first principal component are generally very high. As shown in Figure 2, the Gini index I is the measure with the highest factor loading on the first principal component closely followed by $E_{1,0}$. As mentioned above, the second principal component is strongly associated only with the $E_{\infty,0}$ index. Therefore, it seems reasonable to interpret the second principal component as representing changes in the abundance of the dominant LCC.

However, there are also different criteria for selecting the most suitable measure to be used as a surrogate of the first principal component. For example, as suggested by Magurran (1988), an effective evenness measure must be able to distinguish between landscapes with similar LCC abundance structures. The index effectiveness will therefore depend on the range of values it takes over the landscapes of interest. In this view, as shown in Table 1, $E_{2,0}$ is the measure with the highest coefficient of variation (CV = 0.258).

One additional criterion proposed by He and Orlóci (1993) is that the selected evenness measure be interpretable in information-theoretical terms. In this view, the evenness measures derived from Hill's (1973) generalized evenness family $E_{\alpha,0}$ are monotone transformation of Rényi's (1970) measure of divergence

$$H_{\alpha}(Q \parallel P) = \frac{1}{\alpha - 1} \log \sum_{i=1}^{S} \frac{q_i^{\alpha}}{p_i^{\alpha-1}} \tag{8}$$

where $P = (p_1, p_2, \ldots, p_N)$ denotes an a priori (i.e., reference) relative abundance vector, and $Q = (q_1, q_2, \ldots, q_N)$ the observed abundance vector. $H_{\alpha}(Q||P)$ measures the information gain on P contained in the observation of Q and is defined only for $p_i > 0$ ($i = 1, 2, \ldots, N$) and if there is a one-to-one correspondence between the elements of P and Q (Rényi 1970). For a perfectly even reference vector P (i.e., if $p_i = p_j$ for all LCC pairs $i, j = 1, 2, \ldots, N$), Hill's (1973) parametric evenness $E_{\alpha,0}$ is related to $H_{\alpha}(Q||P)$ by the simple expression (Ricotta and Avena, unpublished data)

$$H_{\alpha}(Q||P) = -\log E_{\alpha,0} \tag{9}$$

Therefore, both measures $E_{1,0}$ and $E_{2,0}$ might be adequate surrogates of the first principal component within the context of a general theoretical framework based on information theory.

In addition, the evenness measures derived from Hill's (1973) generalized evenness family $E_{\alpha,0}$ are also particularly adequate evenness figures in their relation to diversity. As pointed out by Bulla (1994), since diversity can be informally partitioned into richness and evenness, an ecologically meaningful evenness measure should be such that, when multiplied by LCC richness N, it will produce an index of landscape diversity. Generally, no such formal relation can be derived. However, $E_{\alpha,0}$ is formally related to Hill's generalized diversity N_{α} by the simple expression (Ricotta and Avena 2000) $N_{\alpha} = E_{\alpha,0} \times N$.

7. Conclusion

We tested here the mutual relatedness of seven standard measures of evenness. Principal component analysis was used to identify two individual components that represent the most important aspects of the distribution of abundance among LCCs. We further suggest that these two principal components can be represented in a simpler way by two evenness measures. The second principal component is clearly associated to changes in the abundance of the dominant LCC and can be best represented by $E_{\infty,0}$. Conversely, regarding the first principal component, the choice depends to some extent on the user's requirements. Nevertheless, due to its direct interpretation in information theoretical terms, our recommendation for surrogating the first principal component is $E_{1,0}$.

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References

Alatalo, R.V. 1981. Problems in the measurement of evenness in ecology. Oikos 37: 199-204.

Anon. 1992. CORINE land cover: a European Community project presented in the framework of the International Space Year. *In* Proceedings of 1992 European Conference of the International Space Year. Commission of the European Communities. Brussels.

Baker, W.L. and Cai Y. 1992. The r.le programs for multiscale analysis of landscape structure using the GRASS geographical information system. Landscape Ecology 7: 291-302.

Basak, S.C., Balaban, A.T., Grunwald, G.D., Gute, B.D. 2000. Topological indices: their nature and mutual relatedness. J. Chem. Inf. Comput. Sci. 40: 891-898.

Bulla, L. 1994. An index of evenness and its associated diversity measure. Oikos 70: 167-171.

Camargo, J.A. 1992. Can dominance influence stability in competitive interactions? Oikos 64: 605-609.

Ciancio, O., Corona, P., Iovino, F., Menguzzato, G., Scotti, R. 1999. Forest management on a natural basis: the fundamentals and case studies. Journal of Sustainable Forestry 1/2: 59-72.

Forman, R.T.T. 1995. Landscape Mosaics. Cambridge Univesity Press: Cambridge.

Forman, R.T.T. and Godron, M. 1986. Landscape Ecology. Wiley: New York.

Fuller, R. and N. Brown 1996. A CORINE map of Great Britain by automated means. Techniques for automatic generalization of the Land Cover Map of Great Britain. International Journal of Geographical Informations Systems 10: 737-953.

He, X.S. and L. Orlóci 1993. Comparative diversity analysis of vegetation. Abstr. Bot. 17: 79-86.

Hill, M.O. 1973. Diversity and evenness: a unifying notation and its consequences. Ecology 54: 427-431.

Gustafson, E.J. 1998. Quantifying landscape spatial pattern: what is the state of the art? Ecosystems 1: 143-156.

Lande, R. 1996. Statistics and partitioning of species diversity, and similarity among multiple communities. Oikos 76: 5-13.

Loehle, C., Li, B., Sundell, R.C. 1996. Forest spread and phase transitions at forest-prairie ecotones in Kansas, U.S.A. Landscape Ecology 11: 225-235.

MacGarigal, K. and B.J. Marks 1995. FRAGSTATS: spatial pattern analysis program for quantifying landscape structure. USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-351: Portland, OR.

Magurran, A. 1988. Ecological Diversity and its Measurement. Princeton University Press: Princeton, NJ.

Milne, B.T., A.R. Johnson, T.H. Keitt, C.A. Hatfield, J. David and P.T. Hraber 1996. Detection of critical densities associated with piñon-juniper woodland ecotones. Ecology 77: 805-821.

Patil, G.P. and C. Taillie 1979. An overview of diversity. *In* Ecological Diversity in Theory and Practice, pp. 3-27. Edited by J.F. Grassle, G.P. Patil, W.K. Smith and C. Taillie. International Cooperative Publishing House. Fairland, MD.

Patil, G.P. and C. Taillie, C. 1982. Diversity as a concept and its measurement. J. Am. Stat. Ass. 77: 48-567.

Peet, R.K. 1974. The measurement of species diversity. Ann. Rev. Ecol. Syst. 5: 285-307.

Podani, J. 1993. Multivariate Data Analysis in Ecology and Systematics. A Methodological Guide to Syn-Tax Package. Ecological Computation Series, Vol. 6, SPB Publishing: The Hague, NL.

Rényi, A. 1970. Probability Theory. North Holland Publishing Company: Amsterdam.

Ricotta, C., Corona, P., Marchetti, M. 1999. Informational analysis of forest landscape spatial heterogeneity. Journal of Sustainable Forestry 1/2: 95-106.

Ricotta, C. and Avena G.C. 2000. A parametric index of community evenness. Ecoscience 7: 511-515.

Riitters, K.H., R.V. O'Neill, C.T. Hunsaker, J.D. Wickham, D.H. Yankee, S.P. Timmins, K.B., Jones B.L., Jackson 1995. A factor analysis of community pattern and structure metrics. Landscape Ecol. 10: 23-39.

Rousseau, R., P. vanHecke, D. Nijssen and J. Bogaert 1999. The relationship between diversity profiles, evenness and species richness based on partial ordering. Environ. Ecol. Stat. 6: 211-223.

Routledge, R.D. 1983. Evenness indices: are any admissible?. Oikos 40: 149-151.

Sheldon, A.L. 1969. Equitability indices: dependence on the species count. Ecology 50: 466-467

Smith, B. and J.B. Wilson 1996. A consumer's guide to evenness indices. Oikos 76: 70-82.

Taillie, C. 1979. Species equitability: a comparative approach. *In* Ecological Diversity in Theory and Practice, pp. 51-62. Edited by J.F. Grassle, G.P. Patil, W.K. Smith and C. Taillie. International Cooperative Publishing House. Fairland, MD.

Environmental incompatibility in the competition between territories. The productive valorisation of wooded property

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Abstract

The work we are going to present to the Conference is referred to activities of research about the process's development based on the knowledge of social cultural peculiarities, on the management and valorisation of local resources (environmental, territorial and productive ones). A finality is to try to offer planners, in order to give an up date knowing instrument, useful and able to resolve the actual and emerging problems about wood's resources and the need to conjugate it in a vision of supportability, with the demands of population to which the wood represents a place of spiritual and physical regeneration. The management of woods aims at proving their eco supportability; consistent with the defence of environment the respect of social needs and economic efficiency. The use of geographical information systems (GIS) supporting participation process to planning, represents one of the inquired aspect of the research. This study presented is about a complex territory, its settling, environmental and geographic aspects.
A method to estimate the wooded resource is using the land use map derived from satellite's imagines. In our model we used the calabrian map CORINE Land Cover to find the wooded zone in the places of our interest.

Keywords: Environmental incompatibility, resources, GIS

1. Introduction

The work we are going to present to the Conference is referred to activities of research realised from the DiPiTer of the University of Calabria about the process's development based on the knowledge of social cultural peculiarities, on the management and valorisation of local resources (environmental, territorial and productive ones). A project of development that determined a positive form of collaboration, in which the territory's value and its aspect, as producer of richness, is realised through valorisation and collaboration between different realities, and not through rules belonging to competition and homologation.
A finality is to try to offer planners, in order to give an up date knowing instrument, useful and able to resolve the actual and emerging problems about wood's resources and the need to conjugate it in a vision of supportability, with the demands of population to which the wood represents a place of spiritual and physical regeneration. The management of woods aims at proving their eco supportability; consistent with the defence of environment the respect of social needs and economic efficiency.
The essential thing is to reinforce the capacity to express a self supportable model of development as distinctive feature, this process requires a local culture development because, the local realty can support the relation systems and can determine an increase of non hierarchic nets in social exchanges. The territory's value can't be invented, but it can only grow with local society, valorising the resources already present. Only through a rigorous and careful revaluation of local culture we can give an positive answer to the demands of environmental compatibility very noticed even if the local culture deals as bonds, environmental passages, perimeters and protected zone. Participation, now, become an important factor in planning's process. The use of geographical information systems (GIS) supporting participation process to planning, represents one of the inquired aspect of the research.

2. A case of study

This study presented is about a complex territory, its settling, environmental and geographic aspects, a contest grew along the media valle Crati an drainage basin formed by an interposed depression between the silano and Apennine system. The particular morphologic configuration in a markable way influences the weather producing every year an elevated middle rainfall. The potential vegetation, then, follow this conformation and temperature with a stratification of vegetation on different levels, that goes from Mediterranean bush to beech and pine. We need to underline the existence of a clear dissymmetry between the two sides, caused by the humid draughts that come from west because of the presence of a chain in which there is a condense in the form of rain and fog. The persistence of fog shifts the altitude's bands of vegetation toward the west side, permitting the affirmation of some areales like the beeches, at height of 8000 metres. This different aspect of wood on the mountain and basal level is consequently bond in an enough regular way to the altimetrical heights as well as to humidity, to the temperature and to exposure. The valley and the territory around, present other naturalistic needs, including very remarkable contests. In the biogenetic natural reserves zone, are present a guided and regional reserve.

In this basin we find a settled and complex structure including 29 towns. Such establishments represented a resource in the settling vision, they are developed long the time in a homogeneous way, they grew and formed a whole settled and economic system.

From 1960 the interdependence was interrupted and the interconnection while there was a proliferation of millions of town planning instruments contributing to bring back the different parts of the territory to a cultural and physical isolation. What we want to underline is that in the media valle Crati there is an increase of integration system between the use of the ground and the settling structure and a special way to produce services and supplies. The work in many centres was very strong, in attempt to obtain various economic facilitations, to locate only into the municipal limits all the different potential diversity of use, with the finality to use the planning instrument to obtain the top of resources connected to it or connectable with trade zone, assisted building, rescue zone, till to the actual "Piano Urban". The consequence of this politic was the interruption of the interdependence system that represented the real richness of the whole settling system.

Trying to understand what can be the capacities of the present system, as regards the resources, the inter-connection, the possible inter-relation among the various parts and, to form a system of knowledge aimed to the participation to the top level from the various subjects that use this territory. The characterisation of the resources status, and in particular of the wood resource, of the running form and of the effects of political choices is one of the aims of the project. We cannot give up the diffusion of a good use of the wood resource if we want to preserve our planet from a rapid and irreversible environmental decay.

3. Possible actions

Among the aims of our research, we tried to use the informatic systems to support the process of participation to the planning. The used model was projected to use whole of datas, it is tied to the GIS ArcView of the ESRI and can represent a support for the structuralitation of decided processes without reducing in it the complexity. We used basis-theme; our data are recollected, corrected, georeferenced, transformed and through the ArcView software they are connected to spatial elements with the single theme- attributes. To correlate the environmental issues with the development processes compatible with the places, we opted for a choice of investigation themes strictly connected to the localisation of the resource, which are present in this territory, from the natural and anthropic dangerousness and from the development programs chose from the Municipal Administrations. The elaborated basis theme interested: the use of the ground, planning instrumentals for our country, the environmental and anthropic risk. Our focused model individualised for the various subjects, the minimum units, a value scale aimed to emphasise possible incongruousness among the different themes. The methodology to survey the data is based essentially on the utilisation of air-pictures mainly for the postponement of the information, for the chosen themes everyone liable to rapid alterations during the time. We activated a GIS which, starting from existing information, can be increased and got up to data, useful to various systems of survey and to value present and future tendencies. The study was made with the following data: cartography IGMI 1:25.000, cartography 1:5000, calabrian map CORINE Land Cover 1:100.000, all in the coordinate system UTM (ED 50) georeferenced.

A method to estimate the wooded resource is using the land use map derived from satellite's imagines. In our model we used the calabrian map CORINE Land Cover to find the wooded zone in the places of our interest. The land use map and the covering of the ground one, represent one of the most important information instrument and knowledge at disposal of who work daily in this territory, it is fundamental in the processing of the map about risks, about damages to the natural or cultural environment or in processing of protection measures above objects and areas. Taking advantages associated to the use of GIS we had an articulate and detailed subdivision, (because of the high difference) and a fragmentation of the typologies of the use of the ground. This area is very interesting because of coexistence of good quality environmental and agricultural areas, with town planning. The image given by the data results, has defined homogenous areas in whole territory including 29 countries. This operation permitted to calculate the statistic values about the levels of ground's use, so we pointed out some of the ground's characteristics. The cartographied landscape consists mainly of wooded territory and towns that seem to be concentrated and loose nuclei. The most wooded formations are oak wood, beech wood and mixed wood. The arboreal cultivations and the large olive grove represent an important productive sector. Agriculture is characterised by the sown land.

The second theme was about the informatization of the town planning instruments on the municipal level, in conformity with a dynamic vision regarding the possibility of periodical up gradings.

The third theme was about the environmental and anthropic risk. The collected data regarding geologic-structural information expressed as active faults or as recent tectonic outlines of the crumbliness overflowing areas. Cartographatic events are that ones known according to the studies, also unpublished, developed by the Department of Defence of the Ground, Science of the Earth, Territorial Planning of the University of Calabria, taken from the literature and/or by direct investigations. The collected data are summed in a informative level, inventory in which we reported localisations of all the crumble events which left visible signs on the territory, certain recent faults which can have seismo- genetic importance.
Investigated area, at present, is based on the restitution of risk- maps which delimit zones exposed to dangerous event and on the restitution of map of environmental incompatibility which describe the territory distribution of the event comparing data of other investigated informative. It is clear that at this point of our research, it is possible, thanks to collected and catalogued information in our described Informative System, to make questions on: the current use of the ground/ prevision of Plan; change of the use of the ground during the time; use of the ground/ factors of dangerousness; factors of natural dangerousness and previsions.
This first consideration, in concise way, makes clear the actual resources of territory, their possible level of tutelage and/or valorisation, dangerous level as regards some of the risks. In short a first geography of impacts, concerning the resources, in order to acquire a real knowledge process and to the participation to the future decisions.

References

Balducci, A. 1991. Disegnare il futuro, il problema dell'efficacia nella pianificazione urbanistica. Il Mulino.

Borri, D. 2001. Rigenerare città e ambienti per il mercato o per pluralità di vite?. in Urbanistica n°114, pp.3-7.

Brivio, P.A., Lechi. G.M., Zilioli, E., 1990. Il telerilevamento da aereo e da satellite. Edizioni Delfino.
Camporesi, P. 1985. Le officine dei sensi. Garzanti.

Craig, W., Harris, T and Weiner, D. Report of Varenius Workshop "Empowerment, Marginanalization and Public Partecipation GIS" , oct. 1998 Santa Barbara (Ca), on line.

Cristiano, D., Ferrarini, A., Orlandini, L., Rossi, P., Zaccarelli, N. 2000. Change detection degli Habitat CORINE nel bacino del torrente Baganza, Parma; attraverso l'indice NDVI. In Rivista Italiana di Telerilevamento n°19, pp.29-35.

Decandia, L. 2000. Dell'identità, Saggio sui luoghi: per una critica della razionalità urbanistica. Rubbettino.

Pignatti, S., Trezza, B. 2000. Assalto al pianeta, attività produttiva e crollo della biosfera. Bollati Boringhieri.

Rossi, F. 1999. Pianificare l'ambiente, che fare?. Rubbettino.Rossi, F., Cristiano, D., De Rosa, G. 2001. Le incompatibilità ambientali nella competizione tra territori. *In* Atti della conferenza nazionale INPUT 2001 (Informatica e Pianificazione Urbana e Territoriale - Democrazia e Tecnologia), Isole Tremiti.

Scandurra, E. 1999, La città che non c'è: Dedalo.

White-backed Woodpecker (*Dendrocopos leucotos*) as a indicator-species for monitoring forest biodiversity

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Abstract
We try to analyze the influence of forest management on habitat diversity and biodiversity preservation. We obtain for beech forests on South-Western Pyrenees a link between presence of White-backed Woodpecker and well conserved plots of forests.

Keywords: Forest structure, biodiversity, Woodpecker, *Dendrocopos leucotos*, beechwood

1. Introduction

Quinto Real forest is a managed beechwood of 3.000 hectares located in Navarra, North Spain. The beech (*Fagus sylvatica*) stands have been managed since 1904 mainly under a shelterwood system.
Quinto Real is mainly a well-conserved forest with some species included in the Red List of endangered species of Navarra like the White-backed Woodpecker (*Dendrocopos leucotos* ssp. *lilfordii*).
The first census of White-backed Woodpecker in Quinto Real forest was made in 1993. White-backed territories showed an aggregated distribution and it appears to be determined by forest structure (FERNANDEZ & AZKONA, 1996).
The aims of this study are:

1. To analyze the influence of forest management on habitat diversity and propose a biodiversity preservation management
2. To study the evolution of the White-backed Woodpecker population over the last eight years
3. To relate presence of White-backed Woodpecker with concrete structure characteristics in the forest.

2. Methods

A habitat classification has been made finding 400 different plots and defining 6 major structure types, which match up with succesional stages (Tables 1 & 2).

TABLE 1: Major structure types of plots

Major structure types	Characteristics	Occupied area (%)
Mature even-aged plots	Mature trees. DBH > 40 cm. Closed canopy	17%
Open mature plots	Mature trees before final cutting. Basal area < 10 m^2/ha. Open canopy	3%
Medium aged even-aged plots	DBH 20 - 40 cm.	31%
Young even-aged plots	DBH 10 - 20 cm.	21%
Uneven-aged plots	Young trees coming up continuosly below the canopy of mature trees.	20%
Old Coppice system plots	Sprouts of low and thin dimensions. Low productivity territories.	8%

Transepts for locate nesting places have been made during the breeding season (march – may).
Collected data have been compared with the results of the census made 8 years ago and sylvicultural treatments carried out in this period have been analysed.

Density (pairs/Km^2) and distribution pattern are analysed in relation to the forest structure, the existence of deadwood and optimal trees for nesting (DBH > 40 cm)

TABLE 2: Dendrobiometric characteristics of the studied plots in relation to major structure types of plots. Presence or absence of White-backed Woodpecker an choice (positive or negative selection of habitat)

Plots	Total height (m)	Age (years)	DBH (cm)	Basal area (m^2/ha)	Choice of plots
Mature even-aged plots	26,0	155,3	38,2	26,9	Positive
Open mature plots	27,3	140,2	35,7	8,5	Negative
Medium aged even-aged plots	21,9	91,2	28,8	28,5	Negative
Young even-aged plots	15,8	45,3	15,0	13,0	Absent
Uneven-aged plots	20,0	119,6	28,4	21,9	Negative
Old Coppice system plots	15,9	113,3	25,6	16,9	Absent

3. Results

1. White-backed Woodpecker makes a positive choice in the even-aged mature plots.
2. Among mature plots, White-backed Woodpecker chooses (selects positively) those with a stock of dead wood.
3. Through out Principal Components Analysis (PCA) the first axe defines the 73 % of the variance. The nesting territories of these birds are directly related with positive and high values of axe 1 corresponding to high values of : age, basal area, DBH (diameter to 1,30) and total height.
4. After eight years, global density has decreased from 0,35 to 0,30 pairs/km^2. White-backed Woodpecker has disappeared in those large areas where massive cutting has been made, while his continuance has been guaranteed where small cuttings have been carried out. Mantaining dead-wood standing after cuttings also has a positive effect in the permanence of this bird.

TABLE 3: Dendrobiometric characteristics of the studied plots in relation to occupation or not with territories of White-backed Woodpecker in Quinto Real forest.

Plots	Total height (m)	Age (years)	DBH (cm)	Basal area (m^2/ha)
Without territories	20,1	97,8	26,4	22,7
With territories	25,6	148,7	35,8	26,5

4. Discussion

White-backed Woodpecker lives in well-conserved plots with high species richness so can play the role of "umbrella species" (MIKUSINAKUTESKI *et al.*, 2001).
Selection-forest system is sometimes thought of as being closest to natural conditions (HARRIS, 1997), but in Quinto Real forest, un-evenaged plots are not selected by White-backed Woodpecker because of "sanitary thinning" and selection cutting. After the extraction of deadwood and decaying trees there is no chance for saproxilic insects to live. After the extraction of the biggest trees there is no place to nest. As a result these plots are a low quality habitat for Woodpeckers.
On the other side, evenaged plots as a whole, constitue a mosaic with high spatial diversity. Thus, biodiversity global values changes along the productive rotation: young stages are low-diversed while mature stages are high diversed. The equilibrium of areas on different stages is basic for a good conservation status.
Shelterwood system consists of a series of evenaged plots. At the end of rotation, as a crop of tree matures, the plot is thinned heavily in order to develop large seed-bearing crowns and to allow enough

light to reach the forest floor for seedlings to develop there. As young trees, selective thinning is made to reduce competence.

This system appears to be compatible in Quinto Real with the preservation of White-backed Woodpecker whenever cutting large continue plots is avoided. Moreover, forest management must guarantee the permanency of some 5 to 10 large trees per hectare (ORIA, 1991). Dead-wood must stay alongside the rotation till falling by natural reasons.

In Navarra, to appointing an area of 5% minimum inside the forest as "Reserve, running in a natural succession" is compulsory by law. These areas permit the existence of the decaying forest stage and they are nucleus of biodiversity, but need to be complemented with extensive measures of conservative management.

5. Conclusions

1. Sylviculture is an adequate tool to make sustainable forest management, but must be implemented by measures adapted to the conservation of ecological processes and endangered species.
2. The equilibrium of plots in different stages of the succession with a sufficient representation of old forest may do production and conservation objectives compatible.
3. The existence in managed forest of large trees for nesting and dead wood for foraging is necessary for the conservation of White-backed Woodpecker.
4. A White-backed Woodpecker population with high density is an excellent indicator of well-conserved forests. White-backed Woodpecker can play the role of "indicator-species" for monitoring forest biodiversity, searching the effects of sylvicultural treatments on the ecosystem.

References

Fernandez, C., Azkona, P. 1996. Influence of forest structure on the density and distribution of the White-backed Woodpecker Dendrocopos leucotos and Black Woodpecker Dryocopus martius in Quinto Real (Spanish western Pyrenees). Bird study 43, 305 - 313.

Harris, E., Harris, J. 1997. Wildlife conservation in managed woodlands an forests. Research studies Press.

Mikusinakuteski, G., Gromadzki, M., Chilarecki, P. 2001. Woodpeckers as indicators of forest bird diversity. Conservation biology 15 (1) : 208 - 217.

Oria de Rueda, J.A. 1991. Influencia de la silvicultura y los aprovechamientos forestales sobre la avifauna. Vida silvestre 70: 2-9. Icona.

ASSESSMENT OF ANIMAL GRAZING PRESSURE ON WOODY PASTURES IN CENTRAL ITALY

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Abstract

Study of natural woody species in pastures is interesting to define management guidelines to preserve herbaceous resources from shrubs encroachment and to evaluate the utilization by grazing animals.
The aim of the current work was the evaluation of herbaceous and woody resources in a pasture located in the Majella National Park. The experimental site is located at an elevation of about 1,350 m a.s.l. and the vegetation consisted primarily of native grasslands associated with shrubs that were in the past controlled by mechanical means.Twelve sampling areas were analyzed in the pasture and in each of them all woody plants were recorded. Dry matter production (foliage and twigs) and browse utilization were computed by image analysis on most representative species. The response of plants to browsing was also estimated by using tagged twigs. Moreover, number of species, specific contribution and pastoral value of herbaceous vegetation were determined. Finally, a comparison between effective and potential stocking rate was performed to define some guidelines for range management.
Pyrus pyraster (33% as number of plants), Rosa canina (33%) and Crataegus monogyna (26%) were the most abundant species and total yield was 68.5 kg ha^{-1} with a very low global rate of utilization (28%). Pyrus pyraster showed a higher percentage of browsed twigs than other shrubs and a more evident production of new twigs after browsing. Shrubby density did not affect the pastoral value (about 28) but it has influenced the sward floristic richness.
Obtained results showed that the current stocking rate is not able to reduce shrubs encroachment and it is necessary to implement appropriate grazing techniques to maintain an open pasture in order to assure the functionality of the local animal farms. Moreover, rational management of pastures can limit the reduction in biodiversity, especially if referred to resources inside a protected area.

Keywords: pastures, shrubs, animal browsing, protected areas

1. Introduction

Rangelands play an important role in maintaining vegetal biodiversity and in pastoral, haunting and tourist activities and they are deeply involved in territory and socio-economic development of mountain areas (Bornard and Cozic 1998). This is particularly true in protected areas where pastoral resources are present with relevant surfaces (Talamucci 1995). In this work a pasture encroached by shrubs was investigated in order to estimate animal pressure on them and to define how animals can control woody plants, that are modified by grazing in shape and in density (Heady and Child 1994). Moreover, some relations between herbaceous and woody species were founded, in order to outline management typologies for pastoral resources conservation.

2. Materials and methods

The experimental site was a 36 ha pasture inside the Majella National Park (Central Italy), with a 3 ha area covered by *Fagus sylvatica*. Studied area is located at about 1,350 m asl, (974 mm average annual rainfall, 12.1 °C average annual temperature) on calcareous soils, with natural grasslands dominated by *Cynosurus cristatus, Trifolium pratense, Bromus erectus, Brachypodium pinnatum* and *Carex sempervirens*. In the pasture were present different shrubs more diffused nowadays for current absence of control by mechanical means as done in the past.
Twelve sample areas (314 m^2 wide) scattered in the pasture were individuated inside which all shrubby plants were measured. For the most common (*Crataegus monogyna, Pyrus pyraster* and *Rosa canina*) 9 plants each were selected and photographed (on July, at the end of vegetative growth) before and after grazing: each image was acquired with digital scanner and analyzed by a specific software (FEPI, Feature

Extraction Plant Image) in order to obtain green volume of the plants and to evaluate DM production and animal intake through appropriate regression equations (Staglianò 1997).
Reaction of plants to browsing was estimated by marked twigs (3 for each plant) that were removed at the end of June to determine DM production while, from July on, the number of new twigs was recorded. Moreover, a synthetic index of utilization was attributed to each shrub (0 = no utilization; 1 = light utilization on some twigs; 2 = heavy utilization on all crown). In each sample area herbaceous vegetation was investigated through linear analysis (according to Daget and Poissonet 1969) to determine floristic richness, specific contribution of all species and pastoral value.

3. Results and discussions

Data collection permitted total assessment of shrubby and woody plants which were divided into 4 height classes (1: $h \leq 0.5$ m; 2: $0.5 \text{ m} \leq h \leq 1$ m; 3: $1 \text{ m} \leq h \leq 1.5$ m; 4: $h \geq 1.5$ m). A total amount of 938 plants ha^{-1} were recorded, being *Pyrus pyraster* (33% as number of plants), *Rosa canina* (33%) and *Crataegus monogyna* (26%) the most numerous species, with low presence of *Acer campestre*, *Quercus cerris*, *Juniperus communis*, *Ligustrum vulgare*, *Prunus spinosa* and *Rubus* sp. Height class number 2 was the most frequent, thus demonstrating the ineffective control of animal grazing in a phase in which (for reduced dimensions) plants could be easily browsed.
Total annual DM production available for animals (leaves and twigs) from the three studied shrubs was about 68.5 kg ha^{-1} (table 1).

TABLE 1 Parameters collected on the three most representative shrubby species

Species	Number of plants ha^{-1}	Average green volume plant^{-1}	DM production kg ha^{-1}	DM intake m^3 plant^{-1}	Utilization %
Crataegus monogyna	218	0.26	20.1	0.02	26
Pyrus pyraster	285	0.33	26.3	0.03	34
Rosa canina	273	0.52	22.1	0.02	23

Such amount is really low, so shrubby vegetation, in studied environment, represents only a complementary forage resource to herbaceous one. Moreover, the utilization rate of woody plants (28% in total) is not very heavy but they are important all the same because they can integrate animal diet in some particular components.
Pyrus pyraster seems to be the most palatable species (34%) and in fact it presented the highest percentage of plants with browsing index 1 and 2 (33% and 9% respectively), while the other two species showed lower data (table 2).

TABLE 2 Percentage of plants in browsing classes and browsing reaction

Species	Browsing indexes			Number of new twigs plants^{-1}
	0	1	2	
Crataegus monogyna	89	10	1	2
Pyrus pyraster	58	33	9	7
Rosa canina	84	13	3	1

The production of new twigs as reaction to browsing was considerable only in *Pyrus pyraster*, thus showing the possibility of reducing its vegetative vigour with the gradual reduction of its reserve supply, extremely necessary for production of new green matter; in this way, it seems that the development of this plant can be controlled through animal grazing. *Crataegus monogyna* produced generally new leaves near the axil of thorns of removed twigs, and only in a few cases it produced new twigs, as *Rosa canina.* It is possible that twigs removal (performed at the end of June) was too late to generate in studied plants a great reaction to simulated browsing, according to reduced duration of vegetative period in such mountain environment. This is probably true especially for *Crataegus monogyna* and *Rosa canina* that are able to accomplish their phenological and vegetative cycle in a shorter period than *Pyrus pyraster* in the investigated environment, considering that some fruits were recorded on them during collection data.
Pastoral vegetation resulted quite invariable in relation to changes in the shrubby stand: number of palatable species for linear analysis, specific contributions of grasses and legumes and pastoral value did not show any correlation with current woody density, thus demonstrating that evolution that involves strong changes in structure of woody vegetation not always proceeds through changes in quality of

herbaceous resources. On the contrary, a significant regression was found between total number of shrubs ha^{-1} and total number of herbaceous species (figure 1).

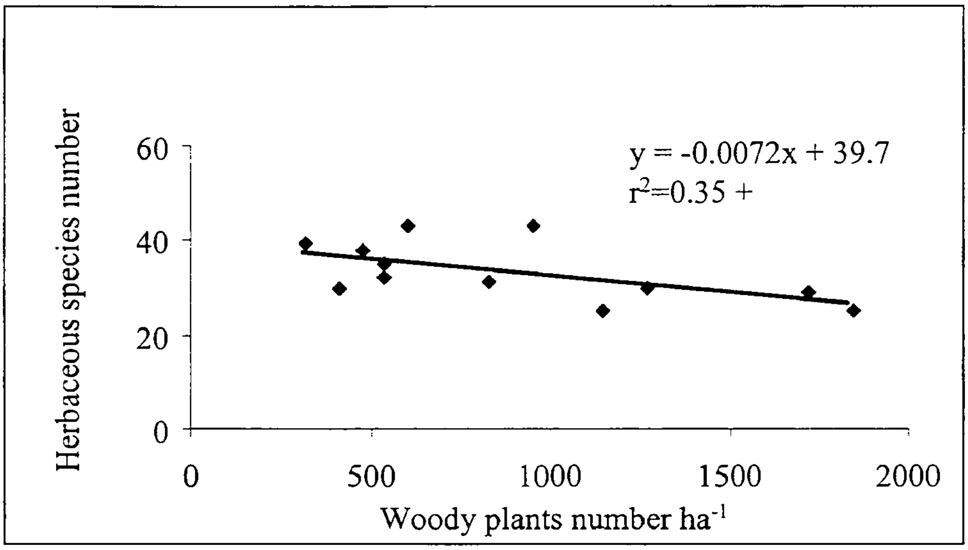

FIGURE 1 Number of woody plants ha^{-1} *vs* number of herbaceous species

Evolution of density of shrubs induces a reduction in floristic richness of swards (highly not recommendable in protected areas), while it does not affect the total quality of the forage resource (pastoral value is significantly high, 28) that showed a relevant stability even in high encroached pastures. The lack, in our case, of a strict relation between presence of shrubs and quality of pasture, should induce to severe management guidelines in order to reduce the process of floristic simplification more than to preserve the potentiality of the pastures. Anyway, a simple survey of the presence of diagnostic species as *Brachypodium pinnatum* and *Nardus stricta* in natural grasslands can suggest that a degradation process is going on, probably to be conducted to not appropriate management practices of the pastures (in examined area, ratio between potential and real stocking rate has been evaluated to be about 0.4) and the encroachment of shrubs is due to this not equilibrate utilization.

4. Conclusions

Showed assessment of natural resources was a contribution to the topic of natural pastures in critical balance with forest resources that can resolve, in relation to grazing management, in the encroachment of shrubs. Even if such resources can contribute to animal supply (in a complementary way to natural grasslands and maybe more under qualitative than quantitative point of view), they show to be not able to limit the exploitation of herbaceous resources because of their restricted intake. Moreover, even if in the short term qualitative decrease of pasture has not been recorded, the guided re-establishment of wood or the maintaining of pastoral resources in good conditions are to be accurately considered, in order to avoid (in the long period) productive and qualitative decline of swards. In this specific case, some techniques could be proposed and, complementary to mechanical means, animal grazing can be applied as an effective control method to be used with peculiar way of implementation: rational grazing techniques, applying diversified instantaneous stocking rate according to different shrubby density; use of mixed animal typologies, in order to reduce their natural selectivity on different palatable species; early and repeated utilization, thus reducing the vigour of shrubs.

References

Bornard, A. and Cozic, P. 1998. Milieux pâturés d'altitude. 1- Intérêts multiples de ces milieux gérés par le pâturage domestique. Fourrages, 153: 81-95.

Daget, P. and Poissonet, J. 1969. Analyse phytologique des prairies. Applications agronomiques. C.N.R.S. - C.E.P.E. Montpellier, doc. 48: 67 pp.
Heady, H.F. and Child, R.D. 1994. Rangeland ecology and management. Westview Press Inc. 530 pp.
Staglianò, N. 1997. Valutazione di risorse foraggere diversificate in aree aziendali liberate dall'agricoltura e destinate al pascolamento con animali selvatici. Ph.D. Thesis, University of Florence: 105 pp.
Talamucci, P. 1995. Colture agrarie e gestione dei pascoli. In "Compatibilità delle attività agroforestali nelle aree protette". Acc. Georgofili, Teramo, 113-131.

A HABITAT CLASSIFICATION OF CLIMAX VEGETATION IN MOUNTAINS OF SOUTHERN SIBERIA

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Abstract

Habitats of climax vegetation at a regional scale and of old growth forests at a local scale were identified over a mountain terrain in southern Siberia using two climatic indices – growing degree days, base, 5°C, (heat resource) and a dryness index (moisture resource). Habitats of vegetation and forests of different structures were mapped.

Keywords: climate, climax vegetation, habitat, Siberia

1. Introduction

The final stage of vegetation succession at a locality is a climax which is determined by an environmental (climate and soil) potential of its habitat. Our goal is to determine those potentials for vegetation complexes (altitudinal belts) of a regional scale and forest types of a local scale. We classified habitats of mountain vegetation of southern Siberia at both regional and local levels using two climatic indices: growing degree days, base 5°C (heat supply) and a dryness index (moisture supply).

2. Methods and Results

We worked within the window 84° and 114° E longitude and 50° and 56° N latitude across the mountain terrain of southern Siberia which includes the following regions: Altai, the East and West Sayans, ranges Tannu-Ola and Sangulen in Tyva, and Transbaikalia. The mountains represent a territory of complex topography with elevations up to 4500 m, causing a great variety of habitats for different vegetation types. We characterized the climate of a habitat by two climatic indices – growing degree days, base 5°C, GDD_5, and dryness index, DI, a ratio of the amount of water that can be evaporated by the heat available and precipitation at a locality. Dryness index is calculated as radiation balance divided by precipitation muptiplied by the latent heat of vaporization (Budyko 1974). Data on temperature, humidity, and cloudiness of about one hundred fifty weather stations were derived from Reference books on climate (1967-1970) and used to calculate radiation balance using the Budyko's approach (Budylo 1974).

2.1 Regional scale

Regional regressions relating radiation balance, GDD_5, and precipitation to topography (elevation) were developed. The digital elevation model of 1 km resolution, DEM (GLOBE 1999), and given regressions were coupled to produce regional maps for radiation balance, GDD_5, and precipitation. The DI image was obtained by dividing the radiation balance image by the image of precipitation multiplied by the latent heat of vaporization of water.

Eight vegetation belts (altitudinal belts) distinct by physiognomy and productivity were found for the mountains of southern Siberia (Smagin et al. 1980): mountain tundra, highland open dark (*Abies sibirica* and *Pinus sibirica*) taiga, middle elevation dark mountain taiga, lowland dark (chern) taiga, highland open light (*Larix sibirica* mixed with *Pinus sibirica*) taiga, middle elevation light (*Larix sibirica* mixed with *Pinus sylvestris*) mountain taiga, lowland (*Larix sibirica* and *Pinus sylvestris*) subtaiga, steppes and dry steppes.

GDD_5 and DI were calculated for 250 weather stations having data on temperature and precipitation. Each station was characterized by a unique vegetation type and ordinated in the climatic space of the two indices employed (Fig. 1). Climatic limits for a habitat of each vegetation type were identified. Our bioclimatic ordination showed that dryness index 2.0±0.3 appeared to be a border to separate forest vegetation from steppe; 1.0±0.1 was a border to separate dark-needled species (*Pinus sibirica* and *Abies* *sibirica*) from light-needled species (*Larix sibirica* and *Pinus sylvestris*); and GDD_5 700°C was a border to separate forest from tundra. These limits were coupled with climatic layers to generate a raster image of vegetation habitat distribution across our mountain terrain. A corresponding vegetation type was ascribed to each habitat (a unique combination of the two indices) resulting into a vegetation map (Fig. 2). The modeled vegetation was compared with existent vegetation using kappa statistics. This comparison showed a good agreement between these two maps (overall kappa 0.44). Among vegetation types, the worse agreement was found for steppe. The current boundary between steppe and forest was caused by human activity (agriculture and pasture) rather than by climate. Forests adjacent to steppes being traditionally human habitats have been under anthropogenic pressure for thousands of years.

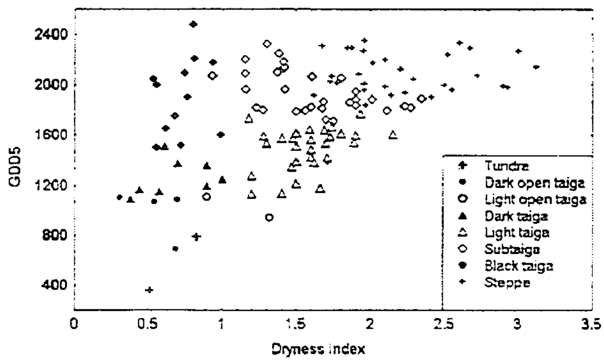

FIGURE 1. Ordination of vegetation types (a) and forest types (b) in climatic space

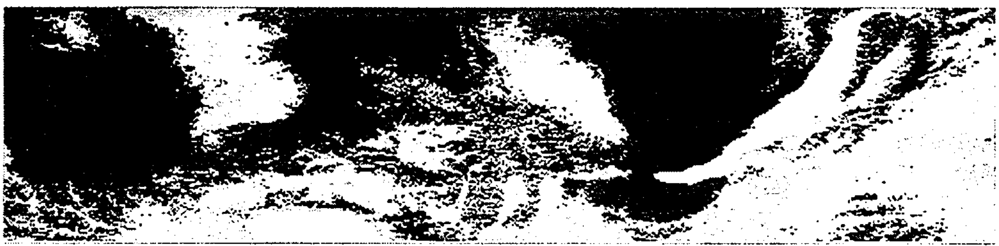

FIGURE 2. Vegetation habibtat distribution over the mountains of southern Siberia: habitats for treeless vegetation (white), habitats for light-leaf forests (grey) and habitats for dark-leaf forests (black)

2.2 Local scale

About one thousand forest plots were selected from forest inventory data along each of three transects across Altai, the West Sayan, and central Transbaikalia from lowlands to highlands to cover a maximum diversity of climates. Each plot was characterized by forest composition (percentage of a tree species in forest composition) and the given climatic indices.

A digital elevation model of 100 m resolution was created by digitizing a topographic map processed with Surfer 6.0, Idrisi for Windows 2.0. Using the Surface module we obtained aspects and slopes layers.

Indices GDD_5 and DI were calculated based on data of 10-15 weather stations adjacent to the transects. Climatic submodels relating topography (elevation, slope and aspect) to climatic parameters were applied to calculate climatic layers of GDD_5, radiation balance, precipitation and dryness index.

Multiple regressions were developed that related a percentage of a tree species in forest composition to a site climate.

A proportion of cedar trees in forest composition is determined :

$N = 145 - 0.05\ GDD_5 - 76\ DI, \quad R^2 = 0.44$

A proportion of pine trees in forest composition is determined :

$N = 39 - 0.06\ GDD_5 + 92\ DI, \quad R^2 = 0.60$

We demonstrate a local approach by using a transect 30 km long and 20 km wide across the West Sayan. Climatic layers and the main tree species distribution in the current climate are shown respectively in Fig. 3 a and b and in Fig. 4 a and b.

Middle elevation sites and highlands characterized by a DI of less than 1.0 are occupied by dark-leaf species cedar (*P. sibirica*) and fir (*Abies sibirica*). Pine (*P. sylvestris*) is found mostly in lowlands in the subtaiga and forest-steppe characterized by DI greater than 1.0. Larch (*Larix sibirica*) is not a dominant tree species across the range analyzed here but may be admixed to both cedar in highlands and pine in lowlands.

a. b.

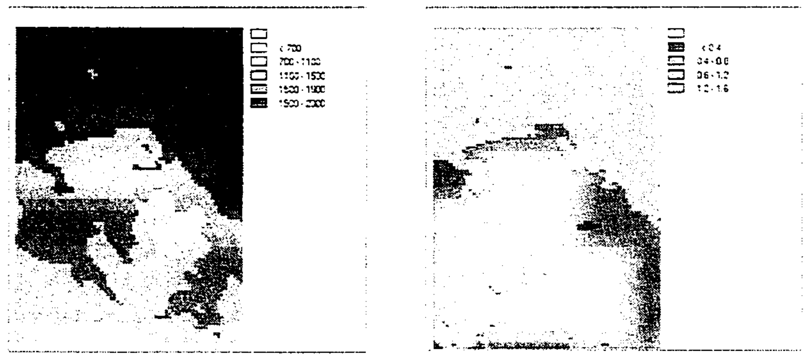

FIGURE 3. GDD_5 (a) and DI (b) distribution across a range in the West Sayan mountains.

a. b.

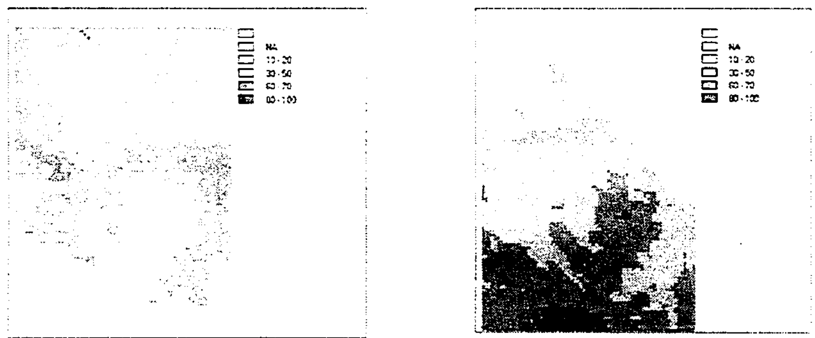

FIGURE 4. Distribution of *Pinus sylvestris* (a) and *P. sibirica* (b) across a range in the West Sayan mountains.

References

Budyko, M.I. 1974. Climate and Life. Academic Press: New York.

GLOBE, 1999. The Global Land One-kilometer Base Elevation. Digital Elevation Model, Version 1.0. (URL:http://www.ngde.noaa.gov/seg/topo/globe.shtml)

Reference books on Climate of the USSR.1967-1970. Gidrometeoizdat: Leningrad.

Smagin, V.N. et al. 1980. *Forest types of the mountains of southern Siberia.* Nauka: Novosibirsk

Plant-phytophagous interactions in pine-forests. Oviposition preferences of pine processionary moth for different host-plants

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Abstract

This paper reports on investigations began in 1981 in various pine-forests composed of several different pine species, located in Tuscany and Latium (central Italy). The aim of the study was to assess host tree influence on behaviour of the pine processionary moth females during the oviposition phase.
Young even-aged pine-forests, with trees of height not above 7 m., were used for the study, to facilitate detection and collection of egg clusters. Egg clusters were collected during autumn throughout the whole period of investigation. Egg clusters were then grouped by provenance, host pine species on which they were laid and were kept separate.
Results indicate that Pinus radiata and Pinus nigra were the most sought species, while Pinus pinea was the least preferred for egg-laying. The lepidopter showed no substantial difference in preference between P. halepensis, P. pinaster and P. sylvestris. More precisely, in mixed stands P. radiata was preferred for oviposition as compared to P. pinaster, P, halepensis and P. pinea while P. nigra was more sought than P. pinaster, P. pinea or P. sylvestris.
This information will be of notable value in forest management as it provides operative guidelines for choice of the pine species most suitable to constitute planted pine plantations, both in open environments and in urban and suburban areas. Not only the damage inflicted on trees by the pine processionary moth can be contained by planting appropriate pine species, but even more importantly, it becomes possible to limit the extent of health problems arising from the action of the irritating hairs of the caterpillars.

Keywords: *Pinus* spp., *Thaumetopoea pityocampa*, oviposition, preferences

1. Introduction

Many oligophagous and polyphagous insects show a remarkable host preference pattern at the time of oviposition, if they are in presence of mixed or stratified forests. For example, the pine processionary moth *Thaumetopoea pityocampa* (Denis et Schiffermüller) shows a marked preference for certain trees compared to others for oviposition, even though all of the trees belong to the range of hosts normally utilised for reproductive cycle. It is known that in the case of the processionary moth, host selection may be influenced by the *Pinus* species (Calas 1897; Tiberi 1983; Masutti and Battisti 1990), on account of needle morphological characteristics (Huchon and Demolin 1970) and nutritional factors (Schopf and Avtzis 1987; Buxton 1990).
Furthermore, tree size, position within the stand and form of the crown are of importance in influencing the choices made by females (Huchon and Demolin 1970; Tiberi 1983).
The purpose of this study was thus to report on investigations carried out over a long year period in some pine forests of central Italy, in order to assess preferences of processionary moth females during oviposition with respect to trees of different species and size.

2. Materials and methods

Observations were conducted in three pine stands in Tuscany and one in Latium. Possible preferences exhibited by females were assessed by counting number of egg clusters laid on individual trees.
In the first pine forest, situated in the municipality of Fucecchio (Florence) at an altitude of roughly 18 m., observations were conducted on 66 roughly fifteen-year-old *Pinus pinaster* and 30 *P. radiata* (= *P. insignis*) trees. For the analysis, trees were grouped into four classes on the basis of height, which varied between 4 and 7 meters. In addition, the height at which egg clusters were laid was recorded, dividing the crown into bands one meter apart starting from the ground up.

The second pine forest is located in the woodland district of Monte Senario (Florence), at an altitude of roughly 700 meters. Observations were carried out for a ten-year period on 70 pine trees, composed of 50 *Pinus nigra* and 20 *P. sylvestris* trees.
In the year 2000 investigations were begun on a recent plantation established in the Municipality of San Casciano Val di Pesa (Florence), at an altitude of roughly 300 meters. For *P. pinea* and *P. nigra*, 25 trees each were examined, and 24 for *P. pinaster*.
Additional investigations were performed in Latium, in a pine grove of the Municipality of Fondi (Latina), situated at an altitude of about 650 m and composed of four pine species: *P. radiata*, *P. pinaster*, *P. pinea* and *P. halepensis*. The number of trees studied varied during the observations as a result of a wildfire that occurred during the summer of 1993. Thus the number of trees dropped from 28 to 15 for *P. radiata*, from 57 to 28 for *P. pinaster*, from 83 to 55 for *P. pinea* and from 35 to 13 for *P. halepensis*.

Data on number of egg clusters collected were log-transformed and processed, either with the two-tail t test or by analysis of variance, considering the pine species as the factor of variability.

3. Results

Findings obtained during the investigations showed that processionary moth attack is not randomly distributed on trees in a given stand. At the moment when females of this lepidopteran lay their egg clusters, they opt for a specific individual among the trees in their vicinity. Choice seems to be mainly influenced by the pine species: *Pinus nigra* and *P. insignis* suffered greater attacks in the various plantations in which they were included.
Thus even the early stages of the investigation, carried out in the Fucecchio pine forest, a significantly ($P<0,01$) higher number of egg clusters were found on *P. insignis* than on *P. pinaster*. A total of 585 egg clusters were collected from this pine forest, of which 328 had been laid on *P. insignis* trees and 267 on *P. pinaster*. The preference could not be affected by height or position of the trees, as the specimens of the two *Pinus* presented no appreciable difference within the stand (Fig. 1).
Similarly, in the Fondi pine forest a greater number of egg clusters were laid on *P. insignis* as compared to *P. pinaster*, *P. pinea* and P. *halepensis*. The statistical analysis showed that the significance level was as much as 1‰ ($P<0,001$) in a comparison between *P. radiata* and *P. pinea*, versus 1% ($P<0,01$) in the comparison between *P. radiata* and *P. halepensis* as well as between *P. radiata* and *P. pinaster*. No significant difference was found in the comparison between mean number of egg clusters collected on *P. halepensis, P. pinaster* and *P. pinea*, although a tendency towards a preference for *P. halepensis* compared to *P. pinaster* and the latter compared to *P. pinea* (Fig. 1).

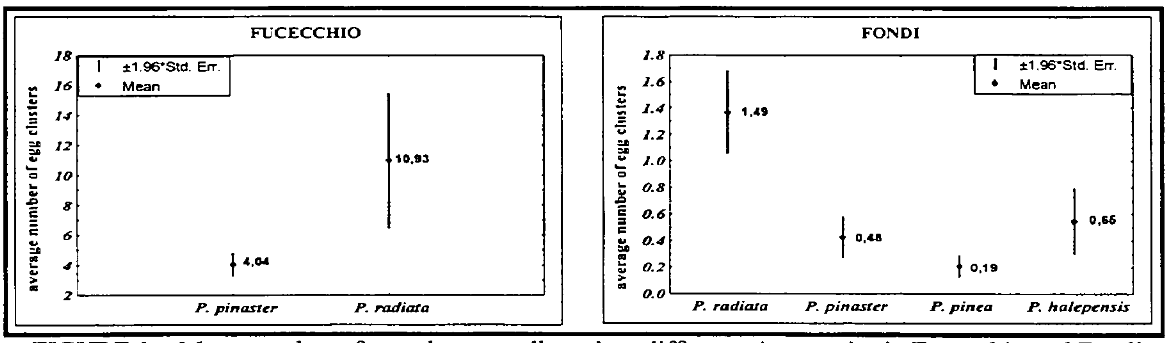

FIGURE 1 – Mean number of egg clusters collected on different pine species in Fucecchio and Fondi stands.

The preference of the pine processionary moth females for *P. nigra* was clear in the plantations where this pine was present. At the Monte Senario site, the overall mean number of egg clusters for the nine years of observation was higher on *P. nigra* than on *P. sylvestris*, although this was not true for each individual year. Statistical elaboration detected no significant differences between mean egg cluster number on the two pine species (Fig. 2). However, *P. sylvestris* is likewise reported in the literature as one of the most sought hosts of this defoliator. In the San Casciano plantation, where *P. nigra, P. pinaster*, and *P. pinea* are present, females of the processionary moth showed a clear preference for *P. nigra* as host on which to lay their egg clusters. Statistical analysis revealed significant differences ($P<0,01$) between the mean number of egg clusters found on *P. nigra* versus *P. pinaster* and *P. pinea*. The latter species was the least sought by the defoliator, although the difference in mean egg cluster number on *P. Pinaster* versus *P. pinea* was not significant (Fig. 2).

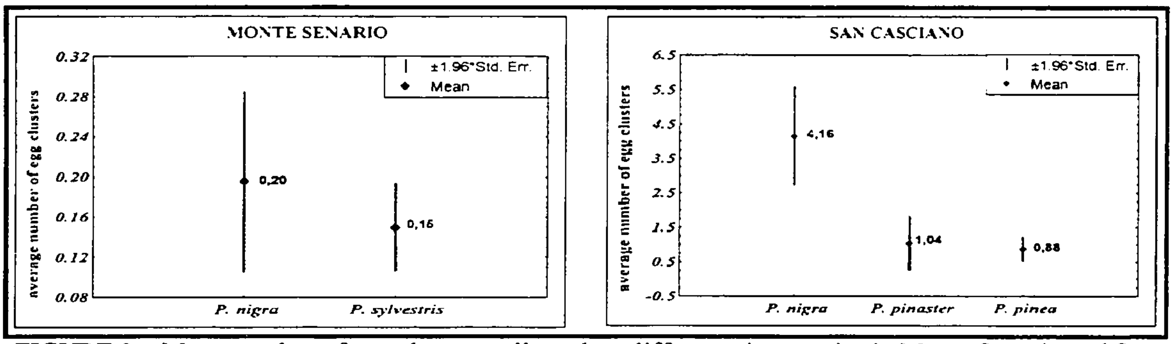

FIGURE 2 – Mean number of egg clusters collected on different pine species in Monte Senario and San Casciano stands.

Possible differences in egg cluster number due to different height were also investigated during the observations conducted at the Fucecchio site. Results showed that the greatest number of egg clusters were laid in the upper parts of the crown, regardless of tree height. In detail, less developed pine trees, i.e. those not exceeding 4 or 5 meters in height, had a greater number of egg clusters in the apical portion of the crown. In the same way the ovipositing females preferred the high parts of the crown also on trees reaching a height of 6 or 7 meters, neverthless they laid more egg clusters on the ramifications just below the apical portion (Fig. 3).

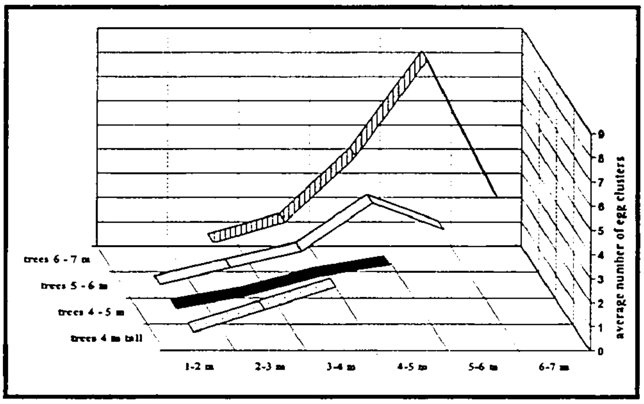

FIGURE 3 – Mean number of egg clusters collected on the different portions of the crown in pines of different height.

REFERENCES

Buxton, R.D. 1990. The influence of host tree species on timing of pupation of Thaumetopoea pityocampa Schiff. (Lep. Thaumetopoeidae) and its exposure to parasitism by Phryxe caudata Rond. (Dipt., Larvaevoridae). J. Appl. Ent. 109: 302-310.

Calas, J. 1897. La Processionaire du Pin(Cnethocampa pityocampa). Rev. des eaux et forêt: 705-723.

Huchon, H., Demolin, G. 1970. La bioécologie de la Processionnaire du pin, dispersion potentielle, dispersion actuelle. Rev. For. Franc. n. spéc. "La lutte biologique en forét - 1970": 220-233.

Masutti, L., Battisti, A. 1990. Thaumetopoea pityocampa (Den. & Schiff.) in Italy. Bionomics and perspectives of integrated control. J. Appl. Ent. 110: 229-234.

Schopf, R., Avtzis, N. 1987. Die Bedeutung von Nadelinhaltsstoffen für die Disposition von fünf Kiefernarten gegenüber Thaumetopoea pityocampa (Schiff.). J. Appl. Ent. 103: 340-350.

Tiberi, R. 1983. Sulla distribuzione delle ovature di Thaumetopoea pityocampa (Den. & Schiff.) in un giovane impianto di Pinus pinaster e P. insignis. Redia, LXVI: 603-614.

Development of an authenticity-index for forests, as a performance-evaluation-tool for forest management in function of biodiversity

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Abstract

Ecological aspects are increasingly influencing silvicultural management. Estimating forest biodiversity has become one of the major tools for evaluating management strategies. This paper presents a standardised and practical methodology for the monitoring of some important aspects for biodiversity in forests, that are both easily measurable and susceptible to changes through silvicultural measures : stand structure (both vertical and horizontal), species composition of the tree- and shrub layer, species composition of the herbal layer and dead wood elements (both standing and lying coarse woody debris). A scoring system was developed for each of these aspects, based on relevant data on a stand-scale level provided by the forest inventory for Flanders (Belgium).

Test calculations were performed and prooved the index to be sensitive to changes due to management and to be reflecting the actual structural and compositional diversity of forest stands.

A validation to actual species diversity was performed through the inventory of a selected number of fauna taxa (invertebrates) in 50 plots covering all major forest types of Flanders. High scores however did not always reflect high species diversity of the selected groups. Some groups even reacted oppositely to different parameters of the index. Other aspects which are not included in the index, such as forest and stand size, management history, soil and litter type, seem to be more determining for absolute species richness (which is not necessarely a good measure for biological value).

Therefore the index is not described as a 'biodiversity-index' but as an 'authenticity-index', as defined by Dudley (1996) : a reflection of the extent to which a forest corresponds to a naturally functioning forest in terms of composition and ecology, and thus a measure for 'potential biodiversity'.

Keywords: Authenticity, biodiversity-evaluation-tool, forest-inventory, indicator

1. Introduction

Forest ecosystems are important in preserving biodiversity. The engagements taken at the UNCED (CBD) and a number of european initiatives like Helsinki resolution 2, Pan-European Biological and Landscape Diversity Strategy (PEBLDS) have lead to the 'European Work Programme on the Conservation and Enhancement of Biological and Landscape Diversity in Forest Ecosystems (WP-CEBLDF). First objective of this work-programme is to identify indicators for evaluation of biodiversity in forest ecosystems both on national and subnational level.

The Flemish government also has committed itself to fulfil the obligations towards biodiversity conservation in forests. Therefore there is a definite need for monitoring tools for biodiversity in general and forest biodiversity performance in particular.

Direct assessment of this performance through monitoring of species richness is labour intensive, time consuming and requires specialist knowledge, which makes it inapplicable on a large scale.

An alternative approach consists of the use of sets of biological and/or structural indicators. In this study the development of an evaluation-index for forest biodiversity on the level of a forest stand was intended based on available data on forest structure and floral species composition from the forest inventory. It covers easily measurable features of forest structure, woody and herbal layer composition and deadwood, serving as indicators for biodiversity. The concept of the index and its indicators is based on a virtual image of the authentic structure and composition of primary natural forest ecosystems. The index is conceived under the assumption that a varied and complex forest structure induces a high biological richness due to the creation of a diversity of different niches (Altenkirch 1988; Franklin 1988). As it will serve as a monitoring tool to evaluate the impact of forest management on biodiversity, a high sensitivity to silvicultural measures is necessary. This requirement outrules other important indicators of biodiversity like site history, connectivity, forest area, site condition, etc. (Van Den Meersschaut and Vandekerkhove 2000).

2. Aims and methods

2.1 Strategy

The main aim of this project was to produce a standardised and practical methodology for the monitoring of some important aspects for biodiversity in forests, that are both easily measurable and susceptible to changes through silvicultural measures :

- stand structure (both vertical and horizontal)
- species composition of the tree- and shrub layer
- species composition of the herbal layer
- dead wood elements (both standing and lying coarse woody debris)

A scoring system was developed for each of these aspects, based on relevant data on a stand-scale level provided by the forest-inventory for Flanders (Belgium). Each aspect was divided into several parameters which are seperately measured and scored.

A tool for automatic calculation of the index was also developed, allowing an immediate large scale application without major extra effort over 1300 plots of the Flemish forest inventory, thus allowing the overall evaluation of Flemish forests on their current status for these 4 important aspects (Van Loy and Vandekerkhove 2001).

Larsson et al. (2001) suggest to link the monitoring of forest biodiversity to the national forest inventories, as these inventory programmes are especially designed to reflect changes in the status of selected indicators.

2.2 The Flemish forest inventory

The forest inventory of the Flemish Region is based on a systematic sampling technique using a geo-referenced grid of 1 × 0,5 kilometre (Waterinckx and Haelvoet 1997). Due to a low forest index of 10 percent and a high degree of fragmentation, only a limited number of intersections of the grid are actually situated in forest resulting in approximately 2600 plots.

The forest inventory includes a general description of the stand, combined with measurements of the woody and herbal layer (Waterinckx and Haelvoet 1997; Afdeling Bos en Groen 2001). Herbal layer is recorded in only half of the plots (approx. 1300 plots), widening the grid to 1 x 1 km.

The general stand description includes stand type (high forest, Coppice with stardards, Coppice), estimated or recorded age of the stand, canopy closure (1/3; 1/3-2/3; >2/3), horizontal structure (one storey, multi-storey) and vertical stand structure (homogeneous, group-mixed line-mixed or individually mixed stand).

The woody layer is sampled using a nested plot design of 4 concentric circular sample units (A1, A2, A3 and A4) with variable radius (R1, R2, R3 and R4) according to the dimension of trees and shrubs (FIGURE 1).

All trees over 7 cm DBH are recorded in a circular plot (A3) covering about 250 m² : species is recorded, DBH is measured and the individual trees are also positioned using polar co-ordinates. For trees over 40 cm DBH, the circular plot is expanded to about 1000 m², and similar measurements are done. These measurements apply to living as well as dead standing trees (snags). In A1 and A2 species and stem numbers of shrubs, seedlings and small trees are recorded. The herbal layer is sampled on the same spot using a 16 × 16 metres square plot. All vascular plants and mosses are identified and their cover is

estimated using an adapted version of the Braun-Blanquet scale (Barkman et al. 1964). Within the plot special attention is given to the lying deadwood (logs). Logs are divided into 4 diameter classes (2 < ∅ < 7 cm; 7 < ∅ < 22 cm; 22 < ∅ < 40 cm and ∅ > 40 cm). Density and stem-length of the logs is estimated for respectively the first and last two classes.
It is the first time that the Flemish forest area is sampled by means of a systematic technique. The Flemish forest inventory will be repeated every ten years.

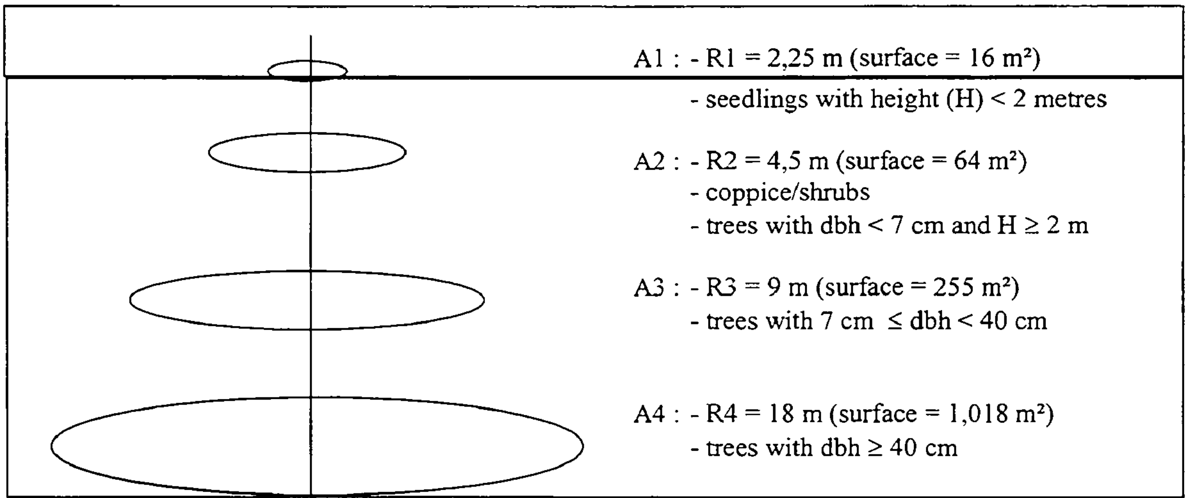

FIGURE 1.--Plot design for the inventory of the woody vegetation consisting of concentric circular sample units (A1,2,3,4) with variable radius (R1,2,3,4) (after Waterinckx and Haelvoet (1997)).

2.3 Elaboration of the index.
As stated the index is composed of 4 aspects (subindices):
1. stand structure (both vertical and horizontal)
2. species composition of the tree- and shrub layer
3. species composition of the herbal layer
4. dead wood elements (both standing and lying coarse woody debris)

Each subindex consists of a set of indicators derived from the available data of the Flemish forest inventory. The indicators are given a score taking into account the 'Delphi technique', which stipulates that, as long as biodiversity cannot be unambiguously measured in the field, biodiversity indicators and their weights or scores can be determined on the basis of a common agreement of different specialists (Alho et al. 1996; Dalkey and Helmer 1962; Kangas et al. 1993).
During application of this technique special attention is given to evenly balancing the weights of the different indicators, presuming their contribution to biodiversity is more or less equal. The maximum score of the index is set to 100. TABLE 1 gives a detailed overview of the score-system with its indicators and their weights. For the indicators of woody and herbal layer composition and dead wood, the classification of the numbers and maximum values are based on analysis of elaborate datasets from the Flemish forest reserve inventory, in which sample plots of comparable size were used (Van Den Meersschaut et al. 1996; Vanmechelen et al. 1997; Viaene et al. 1997), in order to provide realistic cutoff-levels.
Habitat complexity and structural heterogeneity are generally recognised as important indicators for forest biodiversity (Köhl 1995; Noss 1990; Rune 1997; Schuck et al. 1994). The forest structure indicators in this study, are based on a description of the visual characteristics of the whole stand in which a sample plot is located. These characteristics consist of canopy closure or cover, stand age, number of storeys and spatial tree species mixture. Woody layer, herbal layer and deadwood are also part of what can be called forest structure but are treated separately because they are based on actual measurements.
The indicators for the diversity of the woody layer (number of tree species, number of large and very large trees, number of indigenous tree species in natural regeneration and standard deviation of DBH), are all based on measurements in circular sample plots.

Mixed forest stands will accommodate more animal and plant species than single species stands. Exotic tree species make a contribution to biodiversity because a certain, nevertheless limited, amount of organisms can be related to them (Kennedy and Southwood 1984) and because they contribute to forest structure. Therefore they cannot be totally neglected. However if their share increases and they start dominating the stand and outcompeting native species they have a negative influence on biodiversity. Exotic tree species are therefore taken into account provided that their proportional share in the total basal area or stem number is less than 5 percent. If their proportional share amounts to 5 to 50 percent, they are treated indifferently. If their proportional share exceeds 50 percent, they are negatively accounted. A similar qualitative appreciation is also applied by Hekhuis et al. (1994).

TABLE 1 : overview of the scoring system based on the forest inventory data in the authenticity index.
(1) For exotic species : if of Basal area or Stem number is < 5%, species are accounted; if coverage is 5-50% they are not accounted; if they cover >50% the score for this subindex is subtracted by 1.

FOREST STRUCTURE	Score	WOODY LAYER	Score	HERBAL LAYER	Score	DEAD WOOD	Score
Canopy Closure		Number of tree species (1)		Number of Plant species		Basal area snags (m^2/ha)	
> 2/3 of the area	2	1-2	1	1-5	1	< 2	1
1/3-2/3 of the area	4	3-4	2	6-10	2	2 – 3,5	2
<1/3 of the area	3	5-6	3	11-15	3	3,6 – 5	3
		7-8	4	16-20	4	> 5	4
Stand age (years)		> 8	5	21-25	5		
1-60	1			26-30	6	Number of large snags (>40cm)	
61-100	2	Number of Large trees (DBH >40 cm)		31-35	7	1	3
101-160	5	1-5	1	35-40	8	2-3	4
>160	7	6-10	2	41-45	9	>3	5
Uneven aged	5	11-15	3	>45	10		
		16-20	4			Stand. deviation on DBH snags	
Number of Storeys		> 20	5	Degree of rareness		10-15	1
1	2			1-5	1	16-20	2
> 1	4	Number of very large trees (>80 cm)		6-10	2	21-25	3
		1	3	11-15	3	26-30	4
Spatial tree species mixture		2-3	4	16-20	4	31-35	5
Homogeneous	1	> 4	5	21-25	5	>35	6
Clustered	3			26-30	6		
Individual	5	Number of indigenous species in nat. regeration		>30	7	Total stem length logs (in plot) (m)	
		1-4	1			1-10	3
		5-8	2	Number of bryophytes		11-20	5
		9-12	3	1-5	1	>20	7
		>12	4	6-10	2		
				11-15	3	Number of DBH-classes	
		Stand. deviation of DBH (cm)		16-20	4	1	2
		10-15	1	> 20	5	2	4
		16-20	2			3	6
		21-25	3	Total cover (%)		4	8
		26-30	4	1-25	1	If class 4 present	+1
		31-35	5	26-50	2		
		> 35	6	51-75	3		
				> 75	1		
MAXIMUM SCORE :	20		25		25		30

Large trees (40 ≤ dbh < 80 centimetres) create important niches for invertebrates, birds, mammals, fungi and epiphytes, thus contributing to biodiversity. This contribution is even bigger for very large trees (dbh ≥ 80 centimetres). Very large trees normally occupy a larger growth area which automatically results in a limited number per sample plot. Both facts explain why large and very large trees are separately scored. In this case no distinction is made between indigenous and exotic tree species because tree size is a structural parameter making the identity of a species of minor importance.

The influence of natural regeneration of indigenous tree species on current biodiversity is probably rather limited. Regeneration diversity is mainly of interest for future biodiversity. However, because of its

sensitivity for silvicultural measures, it is an important parameter for evaluating the impact of forest management on future biodiversity (Bradshaw and Lindén 1997).
Variation in stem diameter and the occurrence of different succession stages in a forest stand are often associated with a high degree of biodiversity (Esseen et al. 1992). The standard deviation of stem diameter is an important mean to express this variation (Bradshaw and Lindén 1997). The calculations are performed for trees with dbh ≥ 7 centimetres.
Diversity and degree of rareness of vascular plants, diversity of non-epiphytic bryophytes and proportional cover of both are used as indicators of biodiversity for the herbal layer.
Floral diversity is considered to have a major impact on faunal diversity. Plants are also very sensitive to silvicultural measures influencing biodiversity. They are easy to inventory and identify, which makes them suitable to serve as indicators. In this indicator all plant species are treated likewise for determining and scoring floral diversity.
The pure quantitative approach for determining floral diversity is supplemented by a qualitative aspect, which takes into account the degree of rareness of all plants. The degree of rareness is based on the occurrence of a species in a geo-referenced grid of 4 × 4 km using a logarithmic frequency distribution (Stieperaere and Fransen 1982). Calculation of the score is explained in Van Den Meersschaut and Vandekerkhove (2000).
Bryophytes also contribute to biodiversity and react even faster to changing environmental conditions than vascular plants (Biernath and Roloff 1993; Roloff and Stetzka 1995). Non-epiphytic bryophyte diversity per area unit is usually smaller than vascular plant diversity. The maximum score is therefore set to a smaller number of bryophyte species.
Spatial variation in proportional cover of the herbal layer contributes to biodiversity (Bradshaw and Lindén 1997). A cover of 50 percent theoretically offers the biggest chance on maximum variation. Chances for equal variation are the same for a cover of 25 and 75 percent. Because the latter is usually related to an increased biomass it scores higher. Plant biomass plays an important role in the foodchain of an ecosystem, thus influencing diversity.
The importance of dead wood for conservation of biodiversity in forest ecosystems is generally acknowledged. The importance of deadwood quantity, occurrence, size and shape diversity and status of decomposition are stressed in relation to specialised invertebrates, fungi and cavity-nesting animals. Snags and logs create different niches to which certain organisms are adapted, and are therefore treated separately in this study. From the available data in the Flemish forest inventory it is possible to calculate basal area, number of large trees and standard deviation of dbh of the snags and total stem-length and number of diameter classes of the logs.
The amount of standing deadwood is expressed in absolute units of basal area.
Large snags (dbh ≥ 40 centimetres) are usually associated with a high diversity of species, including numerous specialised and rare species (Hekhuis et al. 1994; Rauh 1993; Siitonen and Martikainen 1994). Because of their importance and relative rareness the occurrence of a single snag receives a high score.
The standard deviation of stem diameter is an important mean to express the variation in size of standing deadwood. As for the living aspect of the woody layer, the calculations are performed for trees with dbh ≥ 7 centimetres.
The information provided by the forest inventory on the occurance of lying dead wood is limited : only the occuring diameter classes are registered, as well as the total estimated stem-length of large logs (DBH ≥ 40 cm). The diameter classes of the logs are the same as those used in the Flemish forest inventory. These classes are used to indicate variation in lying deadwood. The occurrence of class 4 with the largest logs is extra rewarded.

2.4 Testing the index

After the elaboration of the index, the resulting scoring system was tested on its consistency (does the index value reflect the actual stand diversity) and its sensitivity to changes in management.
The authenticity-index was developed from the basic idea that more diverse forest stands lead to higher biological diversity. However this presumption is mostly based on common sense, rather than measurements. Therefore, a validation of the index was performed through the inventory of a selected number of fauna taxa (invertebrates) in 50 plots covering all major forest types of Flanders.
For each plot, the authenticity-index was calculated and confronted to actual species richness for the following groups : Spiders, Tiger beetles (Carabidae), Diplopoda, Chilopoda, Cerambicidae, Dolichopodidae, Syrphidae and Empididae. The invertebrates were collected using 3 pitfall- and 6 colour-traps on the forest floor. The traps were emptied every two weeks, during one full year (De Bakker et al. 2000).

3. Results and discussion

3.1 Consistency and sensitivity

The biodiversity index was calculated for two types of datasets in order to check if it reflects site and structural variability of forests in Flanders and if it is sensitive enough to indicate changes for monitoring purposes. The first dataset includes 20 sample plots (from the Flemish forest inventory and the forest reserves database) covering the major variability of forest stands and sites in Flanders, varying from young homogeneous pine plantations to old mixed deciduous forests with a rich forest structure and species composition. The second dataset is confined to one forest and covers 10 forest stands with different structure and composition but with similar site conditions. A description of the stands and their scores for the different subindices and the authenticity index are given in tables 3 and 4.

TABLE 3. General description and index scores for the forest stands of dataset one

Forest stand	Description	Scores				
		Forest structure	Woody layer	Herbal layer	Dead wood	Total
Zoniën13	old Beech stand mixed with oak	16	12	11	9	48
Zoniën1	old Beech stand	18	13	7	8	46
Meerdaal7	old oak stand mixed with Hornbeam/Sycamore	18	14	11	3	46
Parike1	mature poplar stand	18	10	11	6	45
Neigembos5	old Beech stand mixed with oak/Ash	16	12	9	3	40
Zoniën27	old mixed stand of Beech, oak and Ash	16	6	11	3	36
84097	relatively old alder stand	17	4	13	2	36
178132	young birch stand	14	3	13	5	35
Neigembos6	young Ash stand mixed with alder/willow	18	4	13	0	35
Neigembos4	old Beech stand mixed with oak	14	11	5	5	35
317103	very young oak stand mixed with chestnut	11	3	13	4	31
257003	young, open homogeneous Scots pine stand	10	6	10	5	31
318113	young homogeneous oak stand	6	1	13	2	22
Jagersborg24d	Young stand with Scots/Corsican pine clusters	10	2	8	2	22
318018	young homogeneous Corsican pine stand	6	2	6	7	21
95120	young homogeneous Scots pine stand	6	2	10	3	21
Pijnven4	relatively young homogeneous Red oak stand	9	6	5	0	20
Pijnven50	relatively young homogeneous Scots pine stand	9	2	6	2	19
251081	relatively old Corsican pine stand	6	2	5	4	17
95053	young homogeneous Scots pine stand	6	1	8	2	17

TABLE 4 : stand description and index scores for 10 different forest stands at the same site (dataset 2)

Forest stand	Description	Scores				
		Forest structure	Woody layer	Herbal layer	Dead wood	Total
Koeimook7	mixed stand with birch/oak and very old scots pine	18	6	7	5	36
Koeimook5	relatively old birch stand mixed with oak	18	4	6	6	34
Koeimook9	mixed Scots pine stand; some very old pines	9	5	9	11	34
Koeimook10	old Scots pine stand mixed with birch	16	3	7	7	33
Koeimook8	old Scots pine stand	12	6	7	6	31
Koeimook6	Relatively old birch stand mixed with oak	13	2	9	5	29
Koeimook4	young birch stand mixed with Alder buckthorn	14	4	6	5	29
Koeimook1	old Scots pine stand	12	5	5	5	27
Koeimook2	young homogeneous Beech stand	11	6	4	0	21
Koeimook3	relatively old homogeneous Corsican pine stand	7	4	7	0	18

The calculated index-values for dataset 1 do reflect the variability in stand composition in a logical way, ranking them in an increasing order. The difference between extreme values amounts to 1/3 of the maximum score leaving enough space for sound distinctions of diversity status between stands. None of the stands reaches half of the maximum score, nor is the score for the four subindices very high. This indicates that none of the stands has reached a semi-natural optimum so that the index may still

significantly increase parallel to an improved stand development. The deadwood aspect, for example, is systematically low indicating its inferior role in general forest management in the past.
Dataset 2 includes young planted homogeneous stands as well as relatively old semi-naturally developed mixed stands approaching the natural situation on the same site. A difference of almost 20 points between these stands indicates a sensitivity of the index for management impacts. Depending on the management regime, stands with low scores can actually remain at the same level or develop to the highest recorded scores and even higher. Thus the performance of management regimes, aiming at higher structural diversity and naturalness can be evaluated.

3.2 Validation

The results of the validation were somewhat disappointing : high scores did not reflect high species diversity of the selected groups : plots with high and low species richness were scattered ad random when ordered along an axis of higher index value. For the most species-rich groups, being Tiger beetles and Spiders, these conclusions were also statistically tested (linear regression), and confirmed : no correlations could be found (Van Den Meersschaut et al. 2001).
Different reasons can be pointed out to explain these results :

1. The selected taxa represent only a small fragment of the total species richness, and may produce a biased image. The applied methodology is especially designed to inventory soil-dwelling organisms. These are very much influenced by to microstructures of the soil, like litter type and volume, humus type, but only to a very limited extent to forest macrostructures which are described and scored by the index (Irmler and Heidemann 1988; Schultz 1998; Bücking et al. 1998; Martikainen et al. 2000; Köhler 1996). Species that have a clear link to these macrostructures like birds, mammals and canopy-dwelling invertebrates are not included in the index.
2. Different species groups produce contradictory results : some plots that are rich in Tiger beetle species proove to be very poor in Spider richness and vice-versa. This confirms the results of other research on this subject suggesting that a single taxon or a combination of taxa cannot serve as reliable indicators for species richness of most other taxa because of contradictory or weak across-taxon correlations (Nilsson et al. 1995; Oliver and Beattie 1996).
3. The species are not differentiated to habitatspecificity and rareness. In that respect one can point out the questionable use of 'total species richness' as a measure for biological value : a short species list covering rare, demanding and typical species can be more valuable than a long list of common, non-typical species. Plots in isolated forest stands can be very rich in species through high influx of non-typical forest species from outside the forest.
4. Other aspects which are not included in the index, such as forest and stand size, management history, soil and litter type, are known to be very determining for absolute species richness. However, these aspects are not included in the index as they are not subject to changes through stand management.

4. Conclusion

This developed index proves to be a usefull, powerfull and very practical tool for the monitoring of the performance of management measures and policies on some important aspects of forest biodiversity. From a practical point of view the system qualifies as a Biodiversity Evaluation Tool (BET) (Larsson et al. 2001).
The suggested stand-scale index combines biological and structural indicators, based on available data from the Flemish forest inventory. This strategy allows an immediate application on the level of the Flemish region without much extra effort (Van Loy and Vandekerkhove 2001). As the forest-inventory is repeated every ten years, continuity of data for monitoring purposes is guaranteed. A major disadvantage of this strategy is the limitation to include other potentially valuable indicators.
The index is not meant to judge different forests on their biodiversity status and certainly not sufficient to compare forests on their value for nature conservation, due to its emphasis on the quantitative aspects of biodiversity.
The indicator choice is based on widely accepted assumptions of increased species richness in relation to a more varied and complex forest structure. However the creation of new niches does not always guarantee that they will be filled in by the expected organism. The disappointing correlation of the index

to absolute species richness for the selected invertebrate groups illustrates the complex relation between parameters that are generally considered to be important for diversity and the actual 'species richness'. Therefore the index should be considered as a monitoring tool to evaluate the impact of forest management on 'biological diversity potential' rather than on the actual species richness itself. That is why it's not called a 'biodiversity-index' but an 'authenticity-index', as defined by Dudley (1996) :' a reflection of the extent to which a forest corresponds to a naturally functioning forest in terms of composition and ecology'.

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References

Afdeling Bos en Groen, 2001. De bosinventaris van het Vlaamse Gewest. Resultaten van de eerste inventarisatie 1997-2000. Ministery of the Flemish Community, Brussels. 500 pp.

Alho, J., Kangas, J. and Kolehmainen, O. 1996. Uncertainty in the expert predictions of the ecological consequences of forest plans. Applied Statistics 45: 1-14.

Altenkirch, W. 1988. Naturschutz im Wirtschaftswald: Bemerkungen aus zoologischer Sicht. AFZ. 43: 684-686.

Barkman, J.J., Doing, H. and Segal, S. 1964. Kritische Bemerkungen und Vorschläge zur quantitativen Vegetationsanalyse. Acta Botanica Neerlandica 13: 394-419.

Biernath, M. and Roloff, A. 1993. Ökologische Zeigerwerte für die wichtigsten Waldbodenmoose. Forstarchiv 64: 9-16.

Bradshaw, R.H.W. and Lindén, M. 1997. RENFORS. Regeneration of natural forest stands for timber production and environmental value. EU progress report. Contract FAIR1-95-0420, Brussels. 35 p.

Bücking, W., Bense, U., Trautner, J. and Hoghfield, F. 1998. Faunenstrukturen einiger Bannwälder und vergleichbarer Wirtschaftswälder, Sechs Fallstudien in Baden-Württemberg zu Totholzkäfern, Laufkäfern, Vögeln. Mitt. Ver. Standortskunde u. Forstpflanzenzüchtung 39: 109-123.

Dalkey,N. and Helmer, O. 1962. An experimental application of Delphi method to the use of experts. Management Science 9: 458-476.

De Bakker, D.; Desender, K. and Grootaert, P. 2000. Determinatie en bioindicatie van bosgebonden ongewervelden. 1. Bioindicatie van standplaatsvariabelen.. Rapport ENT.2000.01, Royal Belgian Inst. For Natural Sciences, Dept. Entomology: Brussels. 146 pp.

Dudley, N. 1996. Authenticity as a means of measuring forest quality. Biodiversity Letters 3: 6-9.

Esseen, P.-A., Ehnström, B., Ericson, L., Sjöberg, K. 1992. Boreal Forests - the focal habitats of Fennoscandia. *In* Ecological principles of nature conservation, pp 252-325. Edited by L. Hansson. Elsevier, London.

Franklin, J.F. 1988. Structural and functional diversity in temperate forests. *In* Biodiversity, pp. 166-175. National Academy Press: Washington.

Hekhuis, H.J., de Molenaar, J.G., Jonkers, D.A. 1994. Het sturen van natuurwaarden door bosbedrijven. Een evaluatiemethode voor multifunctionele bossen. IBN-rapport 078, ibn-dlo: Wageningen. 146 pp.

Irmler U. & Heidemann B. 1988. Die Spinnenfauna des Bodens schleswig-holsteiner Waldökosysteme. Faun.-ökol. Mitt. 6: 61-85.

Kangas, J., Karsikko, J., Laasonen, L. and Pukkala, T. 1993. A method for estimating the suitability function of wildlife habitat for forest planning on the basis of expertise. Silva Fennica 27: 259-268.

Köhl, M. 1996. Assessing and monitoring forest biodiversity in Switzerland and Germany. *In* EFI Proceedings N° 6, pp. 95-104. Edited by P. Bachmann; K. Kuusela and J. Uuttera. EFI: Joensuu.

Köhler, F. 1996. Käferfauna in Naturwaldzellen und Wirtschaftswald. LÖBF-Schriftenreihe, Band 6. Landesanstalt für Ökologie, Bodenordnung und Forsten/Landesamt für Agrarordnung NRW. 283 pp.

Larsson, T.-B., 2001. Biodiversity Evaluation Tools for European Forests. Ecological Bulletins 50: 1-236.

Martikainen P., Siitonen, J., Punttila, P., Kaila, L. and Rauh J. 2000. Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. Biol. Cons. 94: 199-209.

Nilsson, S.G., Arup, U., Baranowski, R., Ekman, S. 1995. Tree-dependent lichens and beetles as indicators in conservation forests. Conservation Biology 9: 1208-1215.

Noss, R.F. 1990. Indicators for Monitoring Biodiversity: A Hierarchical Approach. Conservation Biology 4: 355-364.

Oliver, I. and Beattie, A.J. 1996. Designing a cost-effective invertebrate survey: a test of methods for rapid assessment of biodiversity. Ecological Applications 6: 594-607.

Rauh, J. 1993. Faunistisch-ökologische Bewertung von Naturwaldreservaten anhand repräsentativer Tiergruppen. Naturwaldreservate in Bayern. Schriftenreihe, Band 2. Bayerischen Staatsministeriums für Ernährung , Landwirtschaft und Forsten: München. 199 pp.

Roloff, A., Stetzka, K.M. 1995. Waldbodenmoose als Zeigerpflanzen und Bioindikatoren - Erkennen, Bestimmen, Nutzen. Forst und Holz. 50: 635-642.

Rune, F. 1997. Naturkvalitet i skov. Statusrapport. Indikatorer for naturkvalitet. Identifikation og testning af indikatorer for naturkvalitet i udvalgte terrestriske naturtyper. Forskningcentret for Skov & Landskab. 36 pp.

Schuck, A., Parviaenen, J., Bücking, W. 1994. A review of approches to forestry research on structure, succession and biodiversity of undisturbed and semi-natural forests and woodlands in Europe. European Forest Institute Working Paper No. 3. EFI: Joensuu.

Schulz U. 1998. Beitrage zur heimischen Biodiversität – Wirbellose Tiere in Natur- und Wirtschaftswäldern. Beitr. Forstwirtsch. U.Landesch.ökol. 32: 52-59.

Siitonen, J., Martikainen, P. 1994. Occurence of Rare and Threatened Insects Living on Decaying Populus tremula: A Comparison Between Finnish and Russian Karelia. Scand. J. For. Res. 9: 185-191.

Stieperaere, H. and Fransen, K. 1982. Standaardlijst van de Belgische vaatplanten, met aanduiding van hun zeldzaamheid en socio-ecologische groep. Dumortiera 22: 1-41.

Van Den Meersschaut, D., Strosse, V. and Lust, N. 1996. Bosbouwkundige en fytosociologische basisinventaris in het kader van de beheersplanning. Bosreservaten Neigembos, Parikebos en Zoniënwoud.. Labo voor Bosbouw (University of Gent): Gent.

Van Den Meersschaut, D. and Vandekerkhove, K. 2000. Development of a Stand-Scale Forest Biodiversity Index Based on the State Forest Inventory. *In* Integrated tools for natural resources inventories in the 21st century. Proceedings of the IUFRO conference, August 16-20, 1998 - Boise, Idaho, USA, pp. 340-350. Edited by Hansen and Burk. USDA Forest Service North-Central Research Station – General Technical Report NC212.

Van Den Meersschaut, D., Vandekerkhove, K., Van de Kerckhove, P., Delbecque, F. and Van Slycken, J. 2001. Selectie en evaluatie van indicatoren en uitwerking van een praktisch bruikbare methodologie voor de beoordeling van biodiversiteit in bossen. Eindrapport project Vlaams Impulsprogramma Natuurontwikkeling VLINA/C96/04. Rapport IBW (B) Bb R 2001.009 IBW: Geraardsbergen, 114 pp.

Van Loy, K. and Vandekerkhove, K. 2001. Assessing and monitoring the status of biodiversity-related aspects in Flemish forests by use of the Flemish forest inventory data. *In* Proceedings of the IUFRO-conference Collecting and Analyzing Information for Sustainable Management and biodiversity monitoring with special reference to mediterranean ecosystems. Palermo, Sicily (Italy), 4-7 december 2001. – in preparation.

Vanmechelen, L., Boddez, P. and Hermy, M. 1997. Bosbouwkundige en fytosociologische basisinventaris in het kader van de beheersplanning-Bosreservaten Pijnven, Jagersborg, Grootbroek, Jongenbos, Meerdaalwoud, Heverleebos, Coolhembos, Kolmont, Galgenberg, Lanklaarderbos en Dilserbos. Labo voor Bos, Natuur en Landschap (KUL): Leuven.

Viaene, P., Boddez, P. and Hermy, M. 1997. Bosbouwkundige en fytosociologische basisinventaris in het kader van de beheersplanning - Bosreservaten Koeimook, Op den Aenhof, Melisbroek en Sevendonck. Labo voor Bos, Natuur en Landschap (KUL): Leuven.

Waterinckx, M. and Haelvoet, P. 1997. Operationaliseren en begeleiden van de uitvoeringsfase van de bosinventarisatie van het Vlaamse Gewest. Eindverslag. Afdeling Bosbeheer en Ruimtelijke Informatietechnieken. University of Gent: Gent. 117 p.

CARTOGRAPHY OF VEGETATION BIODIVERSITY IN VAL PELLICE (ITALY)

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Abstract
The main aim of the "Experimental project for the conservation, management and valorization of biodiversity in Queyras and Val Pellice", was the application of new methods and instruments in studying and mapping natural habitats and vegetation species with reference to the DIR. 92/43 of the European Community (EC). This project was developed in the framework of the Interreg II Italy-France program funded by EC.
The analysis of vegetation biodiversity in Val Pellice was carried out through three complementary approaches; habitats mapping, flora inventory and analysis of dynamic processes.
An integration of different tools, such as multispectral satellite images analysis, aerial photographs interpretation and ground survey, were used for delineating the vegetation habitats maps. Various instruments and methods were applied at different scale allowing the realization of a general map of Val Pellice territory at 1:25.000 scale and three maps at 1:10.000 of test areas with specific peculiarities. In order to follow dynamic processes and to predict the possible future evolution of the vegetation landscapes, a temporal analysis was also carried out using aerial photos of different periods.
The flora inventory was performed by means of specific surveys about the local flora associations in a large number of sample areas, geographically referenced as points. The collected data was then organized in a floristic data base and distribution maps of single vegetation species were produced as outputs.
The results of the project showed the usefulness of vegetation habitats maps for planning and management purposes, particularly for the accurate delineation of those included in the EC conservation lists. In fact all the data provided by the project will be implemented in the data base of the Val Pellice Mountain Community to be used by the decision makers as important instruments in the territory planning.

Keywords: biodiversity, vegetation habitat, satellite images, flora inventory

1. Introduction

The alpine environment suffered qualitative and quantitative landscape changes over the last decades. In particular the most important evolutionary trends are the following:

- General increasing of the forest surface. In this framework a relevant aspect was the reduction of the open agricultural and pastoral areas inside the forest;
- qualitative modifications of the forest stands and of the pastoral surfaces at the higher altitudes in relation to a floristic and ecological evolution.

In this context, as a consequence of the progressive neglect of the mountainous areas related to the irreversible decrease of the population in recent times, the traditional man-managed landscape has reversed into a complex pattern of natural and semi-natural habitats that tends to develop towards more stable configurations. In many alpine valleys these land transformations were perceived by the local communities as a mayor loss both on the cultural point of view (depletion of the cultural heritage related to traditional economic activities) and from the biodiversity point of view.
Therefore there is an increasing need of monitoring the present dynamic processes with the aim of planning and guiding the future evolution of the territory.
The general objective of the Interreg II "Experimental project for the conservation, management and valorization of biodiversity in Queyras e Val Pellice" promoted, as Italian partner, by the Val Pellice Mountain Community is to apply new methods and tools in land management and planning. In particular the project addressed to the conservation of the biological heritage, to the economic valorisation of mountainous habitats (forest, grasslands, pastures) and to the aim of correctly informing and making the

populations aware of these problems. To meet such goals a cross-borders planning is required to ensure that preventive measures can be implemented by the authorities at local, regional and national level.

2. Study area and methods.

The Pellice Valley, located in the north-western part of the Cottian Alps, presents a great variety of vegetation environments spanning form the hilly and low altitudes mountain areas to the proper Subalpin and Alpin environments in a Mesalpic phytoclimatic contest.

As the assessment of biodiversity need to include investigations at different spatial and temporal scales, three integrated approaches were used in analysing this area:

- Habitat mapping carried out through integration of remote sensing techniques and ground surveys;
- Flora inventory by means of development of specific data base managed by a dedicated software;
- Study of the dynamic tendency in course in some part of the territory.

3. Habitat mapping

Following the EC DIR 92/43 a biotop is an ecological entity of relevant interest for the conservation of nature, not considering if the area is presently protected by the laws. In this contest vegetation habitats maps of Val Pellice were produced with reference to the CORINE Biotopes manual (European Commission, 1991), promoted by the European Community to standardise the description of the natural environments in the European countries. Two kind of cartographic outputs were produced in the project.

- Map at 1:25.000 scale on the whole Val Pellice territory carried out using remote sensing data integrated by field surveys and auxiliary data (Digital Elevation Model and vector layers). A SPOT 4 image in association with high-resolution aerial photos were used as a reference base for the developing of the map, both interpreting them as separate layer and performing data fusion procedures (Giannetti and Varese 2000).
- Map at 1:10.000 scale on three test windows located in the upper and medium part of the valley. This work was partially done using digital near-infrared photos with a spatial resolution of 4 metres that were interpreted with reference to the information collected on the ground surveys.

4. Flora inventory

In the framework of the project floristic and vegetation data were collected by means of a large number of field surveys carried out in the period 1997 – 2000. All data were registered and organized into the INTERFLOR data base (Selvaggi and Meirano 1998), that is managed by a specific software. The most remarkable peculiarities of this software, designed to record and process floristic and vegetation data, are the following:

- Consultation of the archives of the Italian flora species with the associated ecological and chorological attributes;
- Description of the environmental and geographical data related to each botanical surveys; the data format is standardized and codified in order to list and process homogeneous data.
- Production of specific outputs that can be processed by other software packages in order to extract phytosociological tables, statistical inference and floristic or vegetation maps.

Further advantages are that surveys stations are referred to U.T.M. coordinate system and can be easily implemented in a Geographic Information System (GIS). Relatively simple GIS processing of the georeferenced botanical data allowed to obtain many kinds of thematic maps such as species distribution, biodiversity maps, habitats maps, etc. These derived botanical data, physically and graphically represented by points, can be superposed to other thematic layers (topography, geology, climate, slope, aspect) for further analysis.

It's important to remark that the data analysis permit to easily define rarity and priority of conservation of flora species by comparing recent and past distribution maps, occupancy and occurrence areas of every single species and to produce distribution maps at local, regional or interregional level.

Another important opportunity is represented by the superposition and correlation of floristic or vegetation data extracted from the INTERFLOR software with the habitat polygons derived from the remote sensing analysis; this operation allow to define with better accuracy the classification levels and to refine the boundaries of the vegetation units.

5. Dynamic evolution of the vegetation

This study was performed on two test sites that particularly suffered the neglect of the agricultural practice since the second world war. In order to follow the vegetation evolution of these areas a diachronic analysis of aerial photos was carried out using four flights spanning from 1964 to 1996. In this phase were particularly considered and mapped the secondary invasion phases (Birch and Hazel stands) of the vegetation and this analysis allowed to highlight and mapping the zones showing the most remarkable changes form one date to another.

The results of this preliminary photos interpretation were also compared with previous maps and studies and interpreted considering the local populations memories.

The crucial issue of the work was to find out a model that can describe the local dynamic of vegetation and can be applied to predict the future landscape evolution. .

In this respect the test sites revealed a substantial expansion of secondary forest formation that replaced former herbaceous cover (pastures) in less than 15 years. The dynamic model of the vegetation appeared to be characterised by the following steps:

1. Grassland, pasture area
2. *Calluna* heath
3. Green Alder (*Alnus viridis*)
4. Birch (*Betula sp.*), Hazel (*Corylus avellana.*), and/or Maple (*Acer sp.*), Lime (*Tilia sp.*) and Asch (*Fraxinus sp.*) stands
5. Beech stands (*Fagus sylvatica*)

6. Conclusions

The Alpine environment is one of the most sensitive terrestrial ecosystem in Europe and is presently exposed to considerable environmental pressures that is resulting in irreversible changes of land cover and land use. In this context assessment of biodiversity is a crucial task, and only the integration of different time and space scale instruments allow to understand and follow the various phenomena involved in the recent ecosystems evolution. The results of the project showed that an integrated approach based on habitats mapping, flora inventory and analysis of dynamic processes can fulfil the aforementioned requirements making the biodiversity assessment a useful tool for planning and management purposes.

In particular vegetation maps and flora inventory data can be directly used for the correct definition and delineation of habitats and species included in the EC conservation lists, that should be considered in the territory planning at different levels.

References

European Commission. 1991. CORINE Biotopes Manual. Habitats of the European Community. Data specifications. Office for Official Publications of the European Communities. Luxembourg.

Giannetti, F. and Varese, P. 2000. Cartografia di ambienti montani della Val Pellice (TO) mediante telerilevamento. In "Informazione geografica: innovazione e formazione". Proceedings of the IV ASITA (Federation of the Italian Scientific Association for the territorial and environmental information) National Conference, Genova (Italy) 3-6 October 2000; 881-882.

Selvaggi, A. and Meirano, P., 1998. La banca dati floristico-vegetazionale del Parco Nazionale del Gran Paradiso: presentazione della prima realizzazione. Archivi Geobotanica. Vol. 4: 143-148.

Appendixes

Appendix I - CONFERENCE PROGRAM

MONDAY, 3 DECEMBER 2001

Pre-Conference Workshop: **Outcome discussion of MNTFR and DMMD projects in a European perspective**

TUESDAY, 4 DECEMBER 2001

Introductory addresses

Session 1: **General keynote speeches** (chairperson: Michael Köhl)

Session 2: **Advances and experiences in remote sensing for forest ecosystem inventory and monitoring** (chairperson: Sten Folving)

Session 3: **Advances and experiences in sampling and modelling for forest ecosystem inventory and monitoring** (chairperson: Chris Brack)

WEDNESDAY, 5 DECEMBER 2001

Session 4: **Forest biodiversity assessment and monitoring** (chairperson: Marco Marchetti)

Session 5: **Landscape ecology and habitat classification in view of forest ecosystem assessment and monitoring** (chairperson: Pamela Kennedy)

Session 6: **Selected issues of forest information systems** (chairperson: Goran Stahl)

Session 7: **Forest inventory and monitoring terminology discussion: special session on behalf of the IUFRO WP6.03.02 and SilvaVoc Terminology Project** (chairperson: Roberto Scotti)

Parallel session 8: **European Forest Information System (EFIS) demonstration** (chairperson: Risto Päivinen)

Parallel session 8: **Poster presentation** (chairpersons: Giuseppe Garfì, Tommaso La Mantia)

THURSDAY, 6 DECEMBER 2001

Session 9: **Ideas and experiences in Mediterranean forest ecosystems assessment and monitoring** (chairperson: Piermaria Corona)

Technical Presentation: **A look to the most recent Very High Resolution satellite imagery** (Livio Rossi)

Final discussion (chairperson and closing speech: Risto Päivinen)

FRIDAY, 7 DECEMBER 2001

Post-conference excursion on Mt. Etna (guided by Giuseppe Garfì and Tommaso La Mantia)

Appendix II - CONFERENCE REPORT

Observations and suggestions for the future (Risto Päivinen)

Based on the presentations, interventions and discussions in the conference rooms and at dinner tables, I would like to summarise the main conclusions which our research community should bear in mind when planning and conducting research on information for sustainable forest management.

- Our societies are in a development phase where forest functions other than timber production are gaining in importance. Information needs – especially in the field of non-wood goods and services - are increasing, but unfortunately, as has been demonstrated by some of the conference participants, this has often had no impact on resources available for collecting and analysing information.
- This situation puts a pressure on those developing the collection of information and the methods of its analysis. Information on sustainable forest management should be politically relevant and result in clear messages to other sectors of society. The collection methods should also be cost-effective in producing reliable and sound information.
- In reporting research results, more attention should be paid to assessing the accuracy and cost-effectiveness of the methods used compared to alternative methods available. The benefits of remotely sensed data – the possibility to create automated analyses and frequent measurements with relatively low costs per area unit – should be considered in parallel with field-based methods, aiming at combining both approaches.
- If duplication of work can be avoided, it will increase the cost-effectiveness of the actual research work. Networking – such as has taken place here in Palermo during the Conference – is one way towards that goal. Another field where IUFRO groups would have plenty to contribute with is sharing basic research material through public databases, e.g. data on stem and canopy measurements and spectral reflectance of different surfaces. As data collection is often the most expensive phase of research, it can be expected that data sharing would reduce the total costs of research.

In the following, the chairpersons of the sessions have expressed their views on the issues taken up by the authors of the papers presented during the Conference. The first session consisted of keynote addresses and is not commented in this context.

Advances and experiences in remote sensing for forest ecosystem inventory and monitoring (Sten Folving)

The session covered the whole spectrum from optimizing the collection of ground data, combining and integrating ground data with remotely sensed data to the application of remote sensing data, at the local and at the continental scale. Geographically, it included examples from the Boreal Northern Europe, the Atlantic Western Europe and from the Mediterranean, but also the forests and other land uses of the whole Australian continent were presented. It is important to remember that a session with 7 presentations and following discussion scheduled for, in total, two hours, cannot cover all the progress made in applying remote sensing to inventories and monitoring of forest ecosystems as the title implies, nevertheless, this session gave a very well-balanced selection of research and development issues being focused presently.

The first presentation showed the necessity to perform post-stratification when combining field data with remotely sensed data for deriving large area estimates. It was stressed, that one has to be very cautions to avoid bias when combining data. Masking using ancillary data is not always a good idea. The conclusions were:

- stratify in order only to use data from relevant image segments,
- work on polygon-level, not on pixel-level,
- post stratification gives the best results.

The presentation from Australia on remote sensing for estimating productivity and biomass change gave a very well documented contribution to the documentation on the usefulness of RS for carbon sequestration and thereby to the general applications for the Kyoto and other international protocols. The Australian Continent has been covered by a multi-temporal Landsat TM-mosaic, which forms the basis for the estimates of area and composition changes and the derivation of productivity.

The contribution is very interesting and important for Europe: just in these years the European Commission and the Member States are preparing a Landsat mosaic for Europe which will be user for the second CORINE Land Cover Mapping. The experiences from Australia should be analyzed could be very useful for the future European assessments using this new, so-called, IMAGE 2000 mosaic.

The third presentation presented a method for deriving segment based spectral strata using digital aerial photos. The aim is to secure a more homogeneous set of stand/strata characteristics than can be achieved using "normal" sample plot methods. The method was applied in two test areas, in one of these the hypothesis was confirmed; in the other there were almost no difference. The authors conclude that the fact that plots situated near stand borders can be avoided using the proposed segment based method makes this a superior approach.

In the fourth presentation air photos in time series were used in an Alpine valley to study the land cover change. The general encroachment of trees into former agricultural areas and pastures were described. As it is often very difficult to draw the borderlines between forest and other land cover types in these areas, the authors raised the question if it could not be considered to change the forest definitions to suit the remote sensing tools.

The following discussion concluded that primarily the remote sensing data should assist the forest and environment communities in supplying the needed and relevant data and information, but, also that in cases where new monitoring indicators had to be developed, these could be developed on the "conditions" of the data – spectral information could under certain circumstances most probably substitute the traditional classifications.

Combining spectral and textural information on a stand basis might be more appropriate than the traditional classifications, and in terms of monitoring much more robust. <

Integrating and testing IKONOS and Landsat 7 data for stand level mapping of forest types in Mediterranean conditions was the topic of the fifth presentation. The authors wanted to examine if these data types could be used for, was precise enough for, forest management purposes and for monitoring in a hierarchical per habitat approach. The conclusion was, that the integrative use of these data types for local forest management and forest type monitoring was satisfactory provided the preprocessing was properly performed.

The enhanced Thematic Mapper+ data from Landsat was used for mapping natural and semi-natural land cover types on Sardinia. The aim was to prepare for an operational CORINE Land Cover mapping exercise. The study showed that especially for these types of land cover, problems should be foreseen, not least because the class definitions rarely harmonized with the manifold spectral signatures from natural and semi natural surface types.

The last presentation concerned the relationship or correlation between forest attributes and SPOT-2 HRV data derived NDVI. The study showed that for a well-managed forest area in Western UK, there was a good correlation between NDVI and top tree height, mean diameter and basal area, whereas the correlation with yield classes was very low. The study also confirmed once more that NDVI saturates with very dense vegetation, and that undergrowth causes problems with low tree densities.

Advances and experiences in sampling and modelling for forest ecosystem inventory and monitoring (Cris Brack)

This session focused on the forest sampler's fundamental objective - collecting data in the most efficient or effective manner to provide adequate information for managers or users to make good decisions. Goran Stahl started by examining the potential for more effective monitoring of changes in vegetation coverage by analysing the presence of absence of species in different types and sizes of plots. He concluded that selection and plot size for presence / absence studies can have significant impacts on the potential for warning of changes in coverage - inappropriate plot sizes may not indicate change in coverage until the change have been very dramatic. Lorenzo Fattorini then exposed us to some of the basic statistic theories that are appropriate when designing stratified sampling approaches for estimating the proportion of wooded points. He emphasised the common trade-off in the design of an inventory: simple implementation and calculation verus complex calculation with increased efficiency (or improved precision) of the estimate. He also demonstrated problems of calculating variance without bias when the underlying statistical theories are incompletely considered. His final conclusion, similar to the advice from so many statisticians, is that more samples are better! This introduced the potential for the increased use of a sequential sampling technique - keep sampling until you run out of time.

A case study reported by Matthias Schrueber examined the efficiency of various cluster plot designs when determining wood and non-wood goods and services. The sampling trade-off here was reduced cost of travelling between plots in a cluster as compared to travelling to new clusters and the reduced information value of spatially correlated plots within a cluster. For this study, variograms indicated that a minimum distance of about 200 m for plots within a cluster was necessary to balance the additional useful information with the minimum cost of establishment.

Margarida Tome took us on a slightly different approach by looking at the desires and needs of the resource owners (cork plantation owners) and modellers of growth and yield and decision support systems. She demonstrated that owners were prepared to undertake inventory work, but without assistance much of this work may be wasted with inefficient techniques (long zig-zag transections) that are not completely analysed (e.g. confidence limits not calculated, nor the idea of sampling error well understood by the owners). After discussion with the owners and analysis of the existing inventory data, Margaida was able to estimate a more efficient sampling technique (cluster sampling) that the owners were prepared to use.

Finally, Albert Dudek tried to progress his "dream of collecting all measurements about the forest trees from the safety of an antiseptic and air-conditioned office" by using powerful computers to automatically analyse remote sensing images and predict DBH. Assuming that remote-sensing tools could automatically detect and quantify tree crown cover, Albert used his extensive database of over 3000 crown and DBH measurements to determine a useful regression model. He found a fifth-order polynomial on crown area could explain about 91% of the variation in DBH. However the regression model had significant localised biases that made its use in younger stands unreliable.

In conclusion, this session focused on the importance of the placement, size and number of plots for the efficient and effective sampling. Incorrect or inefficient decisions on where, how many and big plots should be may result in overly expensive inventories and/or inventories that do not provide managers with the information they need in a timely or sufficiently precise fashion.

Forest biodiversity assessment and monitoring (Michael Köhl)

Papers on different aspects of the assessment and monitoring of forest biodiversity were given. The approaches utilise remote sensing techniques, field assessments, geo-statistical methods, development of new indices and a practical example from a national forest inventory.

The major outcome of the presentations and discussions was as follows:

- The application indices for condensing the information collected in resource assessments are important to facilitate the understanding of biodiversity. Indicators have to be however critically validated and their significance and visibility has to be studied.

- The kNN method is a helpful tool to improve the applicability of remote sensing in assessing biodiversity. However, it shows deficiencies when the species diversity and heterogeneity increases.
- The assessment of species diversity is an essential component of assessing and monitoring forest biodiversity. Interpreting results of species diversity assessments it has to be taken into account that any assessment is subject to observer bias, which will result in a (more or less conservative) underestimation of species diversity.
- The assessment of key attributes in field assessments is an essential component of national forest inventory systems. Before data are collected in the field data analysis and interpretation of results should be clearly defined. Assessing data and trying later on to distil some meaningful information is probably not an appropriate approach.

A major question was raised during the discussions and postponed to the final discussion, as it touches not only upon biodiversity but upon other aspects of NWGS as well.

How can quantitative information assessed in surveys be transferred to meaningful, qualitative information?

Landscape ecology and habitat classification in view of forest ecosystem assessment and monitoring (Pamela Kennedy)

This session was dedicated to characterizing forests as one of many, and diverse components of the landscape. Two presentations dealt with procedures which could be used to describe the fragmented nature of the landscape, and the spatial distribution and pattern of forests. The possibility of characterizing and monitoring the landscape in terms of what it offers as a suitable habitat for the existence and survival of so-called 'umbrella' species was also presented. The session was concluded by two talks that introduced the importance of anthropological and socio-economic aspects both in space and time, and how they are fundamental to the understanding of the shaping of our landscape in Europe.

The papers given by C. Kleinn and C. Ricotta dealt with different approaches to produce estimates of the fragmentation status of the landscape. In the former case, it was proposed that in principle a sampling approach could be taken to derive indices describing patterns in the landscape. The advantage of such an approach would be that existing and well-established sample-based large area forest inventories could be used to evaluate patterns in the landscape and furthermore, that it would also be possible to calculate confidence intervals and thus facilitate statistical comparisons. One limitation would be that such an approach could only provide statistical indices with no mapped or spatial representation of patterns or fragmentation. Clearly, such statistics could complement or even be used to validate the mapped outputs from a remote sensing-based approach. In the latter case, two newly developed software packages were presented to calculate the fractal dimension and the local landscape (forest) diversity from image data, by using an adaptive geographic window. The benefit of such a technique is that it operates on a neighbourhood of pixels and not on a fixed pre-defined rectangle of pixels as in more conventional image analysis approaches.

It was not by chance that two speakers presented the results of using a species-habitat approach. In the one case ecological models were derived for selected species and applied at several different study locations across Europe. In the other case, the model was applied at one single location, but through time. In both cases, the concept of a habitat was used as an indicator of conditions perceived to be important for a particular species or group of species. The approach was based on species-habitat relationships whereby variables (*e.g.*, life requisites, spatial requirements etc.,) known, or perceived to be important for a species are used to determine a Habitat Suitability Index (HIS). Satellite image data were used to identify forest areas, and then to compute pixel-wise estimates of variables such as stand height, volume of birch *etc.*, using the *k* Nearest Neighbour (*k*NN) method and field data. The output was a map illustrating the HSI or distribution of habitats calculated as being the 'optimum' in terms of the variables used in the model. When used in conjunction with multi-temporal image data, and historic NFI records, it appeared promising in terms of identifying the changed suitability of a habitat for a particular species. One limitation to such an approach would be that currently, the model does not take into account the influence from human-induced activities, which can clearly have a significant impact on the rating of a habitat's suitability for a species or species grouping under consideration.

The last speakers in this session, dealt precisely with the importance of incorporating information about the cultural value, historical development and past and present activities of human beings, when trying to unravel and understand the evolution of Europe's landscape diversity. One example was drawn from the structural changes in the landscape along the former border between the German Democratic Republic and the German Federal Republic, and a second example from study areas in Tuscany. It was stressed in both cases that there is a need for integrated analyses of geo-referenced data, historical records of land use and practices, ecological data and socio-economic factors. Without such an integrated approach it is impossible to understand the footprint on the landscape which bears evidence to a multitude of factors acting over time and space and which together are responsible for its appearance and characteristics of today.

During the discussions a number of points were raised. The key points were:

- Can existing sampling strategies and plot designs (of NFIs) be used to assess patterns in the landscape?
- Is there a need for wall-to-wall mapping of landscape patterns at regional or European levels?
- Can the species-habitat modeling approach be used for many species and over large geographical regions? How are the so-called significant species selected?
- How can external factors (historical, cultural, socio-economic *etc.*,) be taken into account in the models?
- Can the species habitat modeling approach contribute to the monitoring requirements of Natura-2000? Can the approach be used retrospectively?

- How do you assure that you can obtain sufficient ecological information about a species' life requisites in order to set-up the ecological model?
- What is the minimum density of plot information on the ground required for the *k*NN method in order to ensure reliable results when utilizing different resolution remote sensing data?
- Do we really understand what the HSI really means? Is there, in fact a one to one relationship with the HSI and the actual distribution of a species?
- There is a strong need to verify the model results.
- It could be that more than one model is required to describe the habitat of a single species?

We rely on the knowledge of experts for weighting or ranking the model variables in order of importance for the existence and survival of a species. Is there are more objective way to approach this?

Selected issues of forest information systems (Goran Stähl)

This session comprised a variety of issues, from a description of a prototype for a European Forest Information System (EFIS) to the modelling of risk for wildfire in Italy. The presentation given were:

I: European Forest Information System – EFIS. A step towards better access to forest information. Pamela Kennedy, Sten Folving, Risto Päivinen, Andreas Schuck, Tim Richards, Michael Köhl, Hans Voss, and Gennady Adrienko.

II: Updating forest inventory data by remote sensing and growth models to characterise maritime pine stands at the management unit level. José Uva, Joao Moreira, Margarita Tomé, and Paula Soares.

III: Mapping and monitoring of tree resources outside the forest in Central America. Tatjana Koukal and Werner Schneider.

IV: Wildfire risk potential and expected impact analysis for sustainable forest management. Andrea Camia and Giovanni Bovio.

The presentation of EFIS pointed towards novel possibilities to access European forest information via the Internet. Compared to the current situation, the prototype system appeared to be a substantial step forwards towards a situation where anybody easily can access forest information and make comparisons between countries. One challenge in developing the system is to find ways to utilise the many heterogeneous data sources available from different countries and still make relevant comparisons.

The second presentation illustrated how remote sensing can be used for estimating forest stand parameters, as a means for updating stand data registers. Landsat TM satellite imagery was used for regression based estimates. Another approach was to use growth models for the updating of stand data. The remote sensing based estimates showed poor accuracy at the plot level, but considerably better precision at the management unit level. Inclusion of stand age as an auxiliary variable improved the estimates considerably.

In the third presentation, methods for monitoring tree resources outside forests were presented. They were based on high resolution satellite imagery or aerial photography in combination with field survey. Using high resolution satellite imagery (like IKONOS) special analytical approaches involving image segmentation were used to obtain reliable estimates. A conclusion from the study was that high resolution imagery is needed for remote sensing based surveys of tree resources outside the forest.

In the fourth presentation, the wildfire risk was modelled using information from many different sources. The modelling was performed in steps; in each step different components of the risk were individually modelled, and finally integrated to obtain the overall risk. The presentation was a good example of how data of different kinds can be merged to obtain value-added output.

To some extent, the first and the last presentation shared the problem of integrating heterogeneous data sources to a common system, although the objectives of the two projects were very different. One ambition of EFIS is to produce a high resolution remote sensing based layer of the European forests. With that ambition fulfilled, the system could serve as a basis for models of the kind presented for the wildfire risks.

The two intermediate presentations showed both the state-of-the art of traditional medium resolution satellite based forest inventory, and the potentials and challenges of using high resolution imagery. It was clear from the presentations that moving from medium resolution to high resolution implies that new methods need to be developed in order to utilise the full potential of the data. To a large extent the new methods need to be based on texture in the images rather than pixel-by-pixel spectral reflection only.

Forest inventory and monitoring terminology discussion (Roberto Scotti)

IUFRO Working Party 6.00.00 and SilvaVoc project asked us for assistance compiling the terminology they are taking care of. Appreciating the idea, a small specific session of the conference has been dedicated to discuss it.

Session introductory presentation has been dedicated to explain aims, goals and procedures of terminology work, following the lines of the document produced by SilvaVoc "Short guide to terminology work".

Session aim has been to launch a web based collaborative project involving a sufficient number of researchers to cover the different perspectives that converge on the field of "Forest and Environmental Monitoring". GeoLab.UniFI offered to host the web forum and FEM-Term DataBase.

Discussion involved several people and seemed to be of interest for the auditory at large.

Some interventions supported the idea and expressed the will to contribute to the terminological work. Other speakers were less supportive. Two questions have received particular attention:

a) potential endless conflicts

b) limited effectiveness

Both questions are, to some extent, negatively influenced by a mis-focused goal, assuming that terminology work implies defining standards.

It seems difficult to convey the idea of using scientific terms with reference to documented sources.

Researchers willing to contribute are invited to visit www.geolab.unifi.it for news and notify to scotti@uniss.it their interest.

EFIS demonstration (Risto Päivinen)

A project to build a prototype of a European Forest Information System (EFIS) is currently underway and sets out to contribute to the principles of the EFICS. The work is being carried out under an Administrative Agreement between the JRC and DG AGRI (*"support to the EFICS" No. 15016-1999-05-A1CO ISP BE)* and it has been contracted out *(No. 17186-2000-12 F1ED ISP FI)* to a consortium led by the European Forest Institute.

The ongoing EFIS study (December 2000–March 2002) is to demonstrate that cost effective and user-friendly methods can be utilised to query, combine and process forestry data from different sources and different data providers throughout Europe. It is based on the following principles:

- Utilising the existing data sources. The system itself does not require any additional data collection. The system aims at improving the access and utilisation of existing data.
- Distributed databases. EFIS is essentially a network of databases. The data will stay with original data owner.
- Labelling the data with metadata. Metadata is 'data about data', a standardised list of contents, helping the user to locate the most suitable data
- Use of Internet. The data will be accessible through Internet.
- User designed query. The user can search and utilise a data processing tool for producing user defined products such as tables, figures or maps.

The present version of EFIS was demonstrated by providing the following sample datasets: Statistical data (forest resources, forest products trade flows, socio-economic data). Inclusion of the geo-referenced vector data (country boundaries, NUTS 1/2 boundaries, protected areas, watersheds); and geo-referenced raster data (European forest map, elevation model) are still under preparation.

The challenge for EFIS lies within the creation of a platform independent information system that allows flexible analysis options addressing diverse user needs, access restrictions and rights, and adequate technological possibilities of presentation.

In the long run, there are two main issues to be addressed:

- Maintenance of the technical system, including further development of the user friendly data processing toolkit and resource discovery system, and
- The framework for making data/information available, including agreements with and services for the data providers in the EU Member States.

In order to facilitate world wide access to data sources, EFIS aims at developing into the European component for a Global Forest Information Service (GFIS). The GFIS activities are coordinated by International Union of Forest Research Organisations (IUFRO).

More information: can be found at www.ec-gis.org/efis/ and at www.efi.fi/projects/project.phtml?id=4575C.

Ideas and experiences in Mediterranean forest ecosystems assessment and monitoring (Piermaria Corona)

Seven oral presentations were given, mainly focused on remote sensing and geographic information (GIS) tools and procedures to map and monitor Mediterranean forest ecosystems, at various scales and spatial and spectral levels: from forest stands to countries, from panchromatic to hyperspectral airborne data, from high to very high resolution satellite images.

Main comments:

1. Any current initiative of forest ecosystem monitoring prove to be framed and planned in the context of a relevant use of remote sensing and GIS tools. Distictively, the Earth Observation (EO) sector is now poised on the brink of major changes as it has been much improved by the implementation of very high resolution (VHR) data that may compete directly with the traditional aerial tools.

2. Within Mediterranean forest ecosystem mapping, landscape can be assumed as a mosaic of individual patches representing very different land cover types. In order to define the elementary patch units within natural and seminatural wooded ecosystems according to a "per habitat" approach, suitable reference can be made to stand forest types. The basic concept is to provide forest managers with an operational tool for site discrimination of types of forest under different ecological-management conditions. Remote sensing must be focused to effectively cope with such a target, and satellite VHR images are a major asset in such a view (i.e., experiences suggest that VHR systems, coupled with georeferenced ancillary data by GIS, might meet more than half of typical forest ecosystem information requirements). However, the cost of VHR data must be lowered and new classification approaches (e.g. preliminary segmentation) replacing the traditional "per pixel" methods must be developed for the automated analyses of such kind of images.

3. The future efforts for narrowing the gap between information needs and available data about Mediterranean ecosystems must be conceived within a comprehensive environmental survey framework. In light of this, the utilization of tools like EO&GIS should be widespread, at all survey levels, along with facilitation of technical research cooperation and exchanges (e.g. coordinating networks) between all Mediterranean countries, trying to explicitly involve also Balkan and North African countries. Human resources prove to remain the main component in this context.

Appendix III - SCIENTIFIC AND ORGANIZING COMMITTEES

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Environment and quality of life series.

Improvement of forest inventory/monitoring is needed to cope with the required assessment and understanding of ecosystem attributes on a global environmental and georeferenced scale. Properly targeted application improvements however must be primarily focused on technical advancements in a broad sense. Changes in land cover and in other ecosystem features have a direct impact on the social expectations concerning forests, especially for its links with nature conservation, global climatic changes and recreation activities. On one hand, the increasing concern of people, researchers and public administration for the values of such environments has enhanced the need for reliable and standardised information on forest attributes in the form of statistics, georeferenced data-bases, thematic cartography, etc. On the other hand, inventories are often not fully exploited for actual forest planning and control. This is distinctively true for the issues related to sustainable forest management. Within such a framework, fostering sound forest inventory and monitoring initiatives and extension encourages the technical and organisational development of the whole forestry sector. An increasing impact on forest inventory and monitoring is also expected by the international directives posing the problem of assessing habitat and ecosystem changes with respect to biodiversity conservation and forest externalities.

The Conference was conceived to give participants hands-on workshop exchanges and experiences about inventory/monitoring problems and potential. Special (but not exclusive) reference was made to Mediterranean forest and other wooded ecosystems, and techniques such as remote sensing and spatial analysis in GIS environment. In Mediterranean countries, reliable and internationally comparable information on forest health and protection, wildfires and biodiversity is largely missing or unsatisfactory. This state is in contrast with the wood-production oriented information characteristically provided by current forest inventory and monitoring procedures.

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