THE MODMED PROJECT

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ABSTRACT

The objective of the Modmed project has been the improvement of the understanding of Mediterranean ecosystems dynamics and degradation. The theoretical approach was aimed to clarify the interactions between the major components of Mediterranean vegetation and to produce models to predict system behaviour at the landscape level. Different studies have been conducted to determine vegetation patterns and ecological attibutes of several species in degrading and aggrading Mediterranean environments. To this scope the behaviour of plant species (micro-scale) and plant communities (intermediate scale) had to be examined and modelled in relation to the physical (soil and climate) and the management (grazing and fire) environment. The construction of a simulation model of ecosystem dynamics has been based on a new modular approach integrating knowledge obtained at the individual plant, the community, and the landscape scales.

INTRODUCTION

The link between ecosystem functions and desertification presents a major challenge for formulation of land-use policy in the Mediterranean region. Continuous land-use has resulted in progressive desertification in many areas. Conversely, the release of marginal land from grazing through recent intensification of agriculture and set-aside has resulted in rapid development of vegetation cover in other areas.

The Modmed project has been based on the premise that the prevention and reversal of desertification depends on an understanding of the processes which determine vegetation structure as it is the plant cover which protects the soil from erosion and determines ecosystem function and its response to perturbation (either climatic change or change in land management).

This project was aimed to quantify the interactions between the major components of Mediterranean vegetation and to produce a model to predict system behaviour at the landscape level. This should help to increase the understanding of the dynamics and degradation processes of Mediterranean ecosystems, providing at the same time tools for the evaluation of the impact of changing climate or of different land-use policies in these regions, e.g. through simulating the effects on natural populations of production-limiting policies with associated set-aside of agricultural land.

A modular modelling approach has been used to scale up from the level of the individual plant to that of the landscape thus bridging the gap between species-level and GIS-orientated models. The study was specifically designed to complement other work done in these environments in order to cover major recognized gaps of knowledge and understanding.

METHODOLOGICAL APPROACH

The general ideas and the study approach of the Modmed project have been presented by Mazzoleni and Legg (1998) and by Legg *et al.* (1995). The research project included field studies on species behaviour and vegetation processes and the design and implementation of new modelling tools.

The Modmed modelling approach finds its theoretical base in recent work in Edinburgh (Muetzelfeldt *et al.* 1996) aimed to produce a modelling environment able to cater for a wide range of modelling approaches, including spatial and individual-based disaggregation, as well as the potential use of qualitative approaches.

A fundamental principle of the Modmed project is that successful predictions (maximum generality) will come from modelling the system at a lower level of organization than that at which the prediction are required. The landscape is therefore disaggregated into a collection of communities which respond to grazing and fire through the processes of vegetation dynamics and succession. Therefore, the Modmed modeling system is hierarchical because each landscape-level unit points to an associated community-level model.

In addition to the hierarchical organization, the other principle central to the Modmed modelling approach is that of modularity. The DLL (Dynamic Linked Library) approach has been used to develop a range of community-level models which are totally interchangeable since they present a common interface to the landscape-level model. This allows the use of different modelling approaches, ranging from rules of vegetation changes to differential equations for species dynamics.

RESULTS

Landscape patterns

The Modmed project defined as a priority task the analysis of Mediterranea vegetation landscape dynamics in the last century. A cartographical approach was followed for the study of vegetation landscape changes in the last 50 years at several study sites by comparing aerial photos and statistical records over this period.

The figure below shows an example from Portugal where a major expansion of shrubland occurred between 1947 and 1990. Similar land cover changes were described at several other sites in the Mediterranean region, reflecting recent, socioeconomically driven, land use changes.

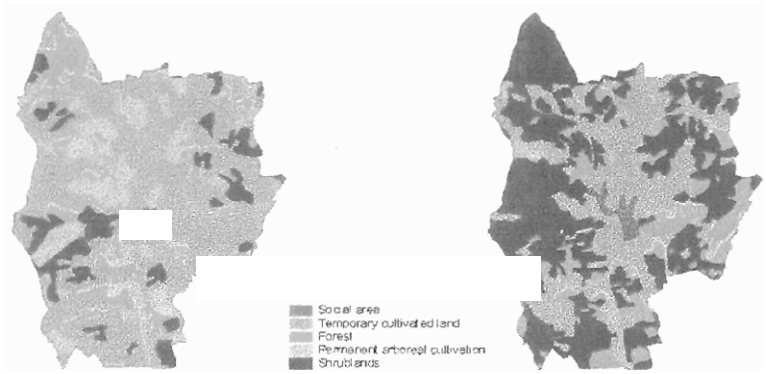

Fig. 1: Land cover changes at Sierra de Malcata in Portugal between 1947 and 1990

Landscape processes

The rainfall distribution, the spread of fire, the distribution of grazing animals, and the long distance dispersal of seeds are ecological processes that are deemed to operate at the landscape level in the Modmed modelling environment. These spatial processes take one or more maps as input and make changes to one or more maps as output.

In the Modmed Landscape model Version 1.0 these processes were all handled by a single programme developed in Delphi Pascal and Visual Basic. Subsequent versions have now been re-implemented in a new modelling environment named Landlord (World-in-a-box Ltd.), which is a component-based, open architecture, spatial modelling system implemented under Windows 95.

The landscape-level model also contains a two-dimensional grid of discrete community-level modules which forms a dynamic vegetation map. The combination of dynamic map collections and process modules can provide time-based simulations of landscape behaviour.

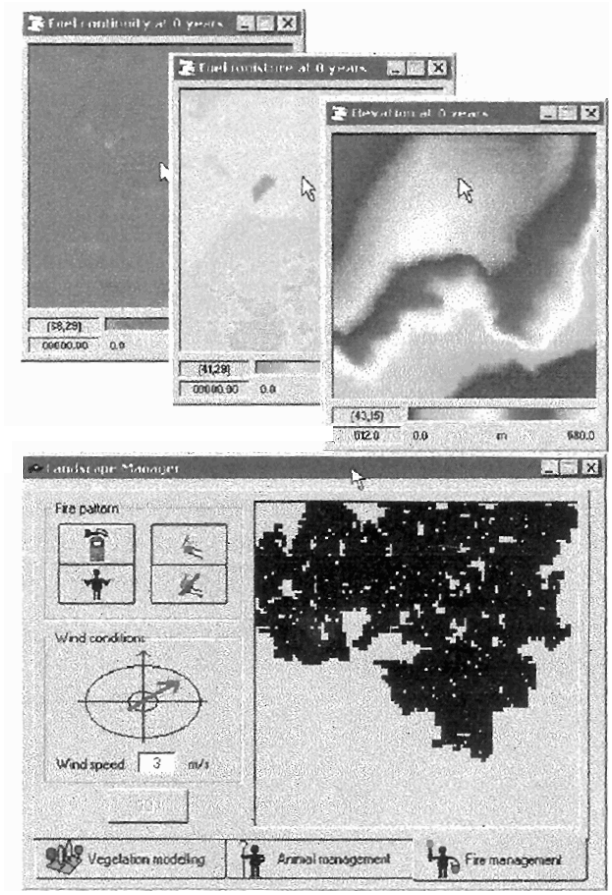

Fig. 2 - Example of input and output maps of the fire spread model in Landlord modeling system.

The possible application of the Modmed approach for modelling the impact of fire and grazing on vegetation in the Mediterranean has been discussed by Legg *et al.* (1997, 1998).

Community patterns

Several activities have been performed within the Modmed project to provide descriptions of community patterns of Mediterranean vegetation. A large database was prepared based on published phytosociological papers on macchia, garigue and evergreen oak forests. This provided large information on compositional changes related to phytogeographical regions and to successional status.

A **stand-alone** computer program called *Comkey* (Legg, unpublished) has been developed to provide the basis for an automated classifier of Mediterranean vegetation. Further implementation of this software should allow its use as a tool for the analysis of species-based community-level models when required.

Major work was performed in Portugal for the study of vegetation structure in several permanent plots (Rego *et al.* 1995, 1996).

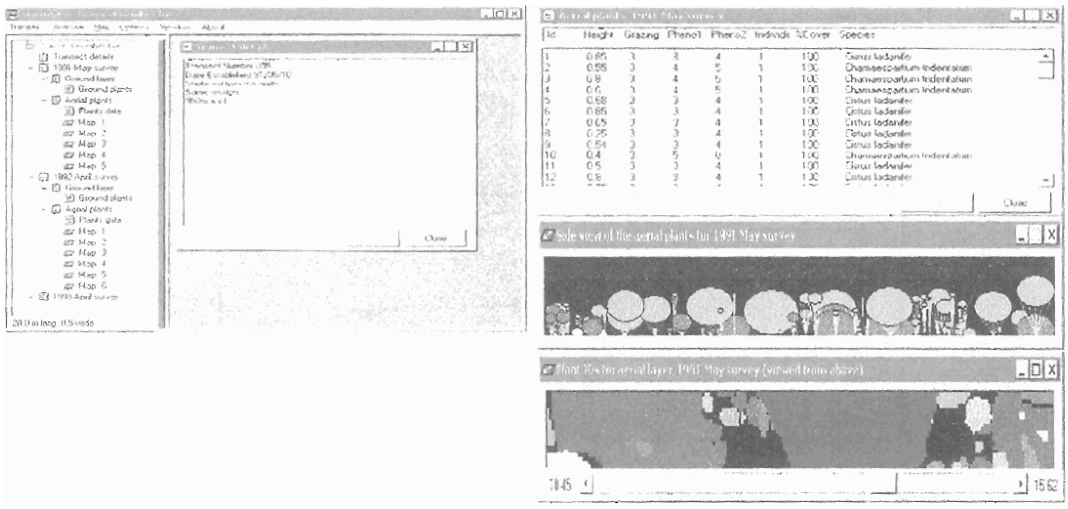

Fig. 3 – Views of the software tool for the analysis of transect data from Portugal

Community processes

Succession analysis have been done by applications of the state transition matrix method on observed transitions in permanent plots and by multivariate analysis of synchronic data of vegetation composition (Rego *et al.* 1994, 1995; Csontos *et al.* 1997; Mazzoleni and Csontos, 1995; McIntosh *et al.* 1995). The studies provided insights in the dynamics of vascular plant communities in Portugal and Italy, whereas a specific study was developed on postfire succession of bryophyte populations in Italy (Esposito *et al.* 1998a, b) .

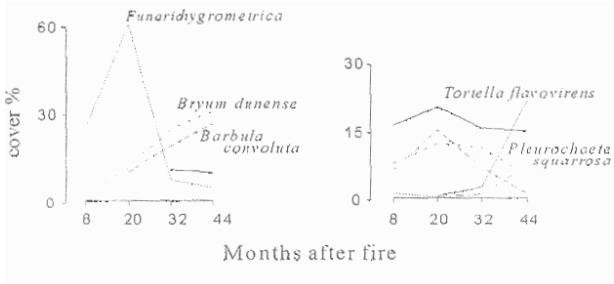

Fig. 4: Post-fire successional trends under different fire intensities of bryophyte population in Mediterranean macchia in southern Italy.

Other studies regarded the seedling establishment potential in different environmental conditions, including investigations in Italy, Portugal and Greece. Beside the publication of papers on the subject (Silva and Rego, 1997, 1998; Arianoutsou, 1998), these data will find application in the parameterization of the demographic model of vegetation dynamic. Some research regarded litter decomposition (Radea and Arianoutsou, 1995).

A multivariate analysis of plant form was conducted in order to relate plant architecture and size to ecological conditions and successional status (Acosta *et al.* 1996a, 1996b, 1997).

Species characters and plant physiology

In the Modmed project several species were studied in terms of their physiology, photosynthesis and traspiration behaviours (Gucci *et al.* 1997a, 1997b,1998; Massai *et al.* 1998; Mingo and Mazzoleni 1998; Mingo *et al.* 1998; Romani *et al.* 1999), phenology (Aronne and Wilcock, 1995, 1996, 1997), and growth and dispersal patterns (Aronne and Russo 1996, 1997).

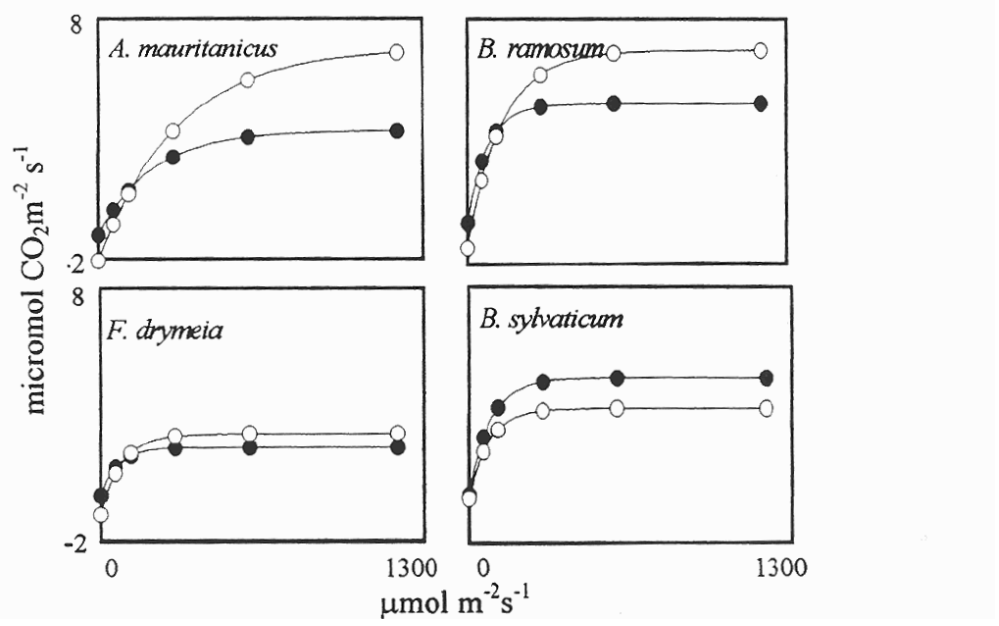

Fig. 5: Leaf photosynthetic rate in mediterranean grasses grown in different environments.

The plant species studied in the Modmed project were selected as representative of different vegetation types ranging from dry and disturbed conditions to mesic and mature successional stages:

Trees	Shrubs	Grasses
Quercus ilex	*Erica arborea*	*Festuca drymeia*
Quercus pubescens	*Phyllirea angustifolia*	*Festuca heterophylla*
Ostrya carpinifolia	*Phyllirea latifolia*	*Brachypodium sylvaticum*
Fraxinus ornus	*Arbutus unedo*	*Ampelodesmos mauritanica*
Acer neapolitanum	*Laurus nobilis*	*Hyparrenia hirta*
Olea europea	*Euphorbia dendroides*	*Brachypodium ramosum*
Quercus rotundifolia	*Myrtus communis*	*Vicia sativa*
Quercus faginea	*Pistacia lentiscus*	*Lathyrus cicera*
Quercus suber	*Rosmarinus officinalis*	*Medicago polimorpha*
Pinus halepensis	*Cistus creticus*	*Hyppocrepis unisiliquosa*
Pinus brutia	*Cistus monspeliensis*	*Brachypodium distachyon*
Carpinus orientale	*Euphorbia acanthothamnos*	*Trifolium stellatum*

Mosses	
Rhynchostegella tenella	*Rhynchostegium megapolitanum*
Hypnum cupressiforme	*Pleurochaete squarrosa*
Funaria hygrometrica	*Tortella flavovirens*

Conclusions

Ecological research has been completed on a wide range of topics at all three levels of spatial and organisational scales. This has included physiological work on several of the dominant shrub and grass species of the study sites, observations on the dynamic processes in permanent plots at the community level, and analysis of vegetation change in the landscape from historic and aerial photographic data.

The modelling work has provided a detailed framework of interactions between the main components of the system. This has been valuable in clarifying the processes occurring at each spatial and organisational levels and has provided stimulus and co-ordination for the field research. Although the complete integration of the individual, community and landscape level models has not yet been achieved, several models have been produced which cross two of the three levels of analysis ranging from rule-based models to spatially-explicit simulation models. The theoretical understanding of the way the system functions has been improved by reconciliation of the modelling and field research approaches through discussion and collaboration throughout the project.

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