Possible effects of climate change on mixed Sub-Mediterranean forests

Nikolaos M. Fyllas, Andreas Y. Troumbis

Biodiversity Conservation Laboratory, Department of Environmental Studies

University of the Aegean, Mytilene, Lesvos, Greece

Introduction

A forest gap dynamics model (Shugart 1984, Bugmann 1996), developed and parameterized for the climatic conditions and forest species of the eastern part of the Mediterranean basin (GREFOS), is used to identify potential impacts of climate change on the structure of forest communities found in the transition zone between Mediterranean and Temperate climate.

For this purpose, four scenarios reflecting potential changes in the current climate of a specific transition zone are developed and applied to the simulator.

Materials and Methods

The model is a 2D, spatially explicit FGD simulator developed in the Visual Basic dot Net programming language, following the structure of Bugmann's FORCLIM model (1996). In order to "Mediterranize" the forest gap dynamics theory we have: (a) calculated the thermal limits of the realized niche for the species included in the model, (b) fitted a modified drought response function, (c) based the mortality and regeneration process on a life-history strategies classification and (d) added a simple fire submodel.

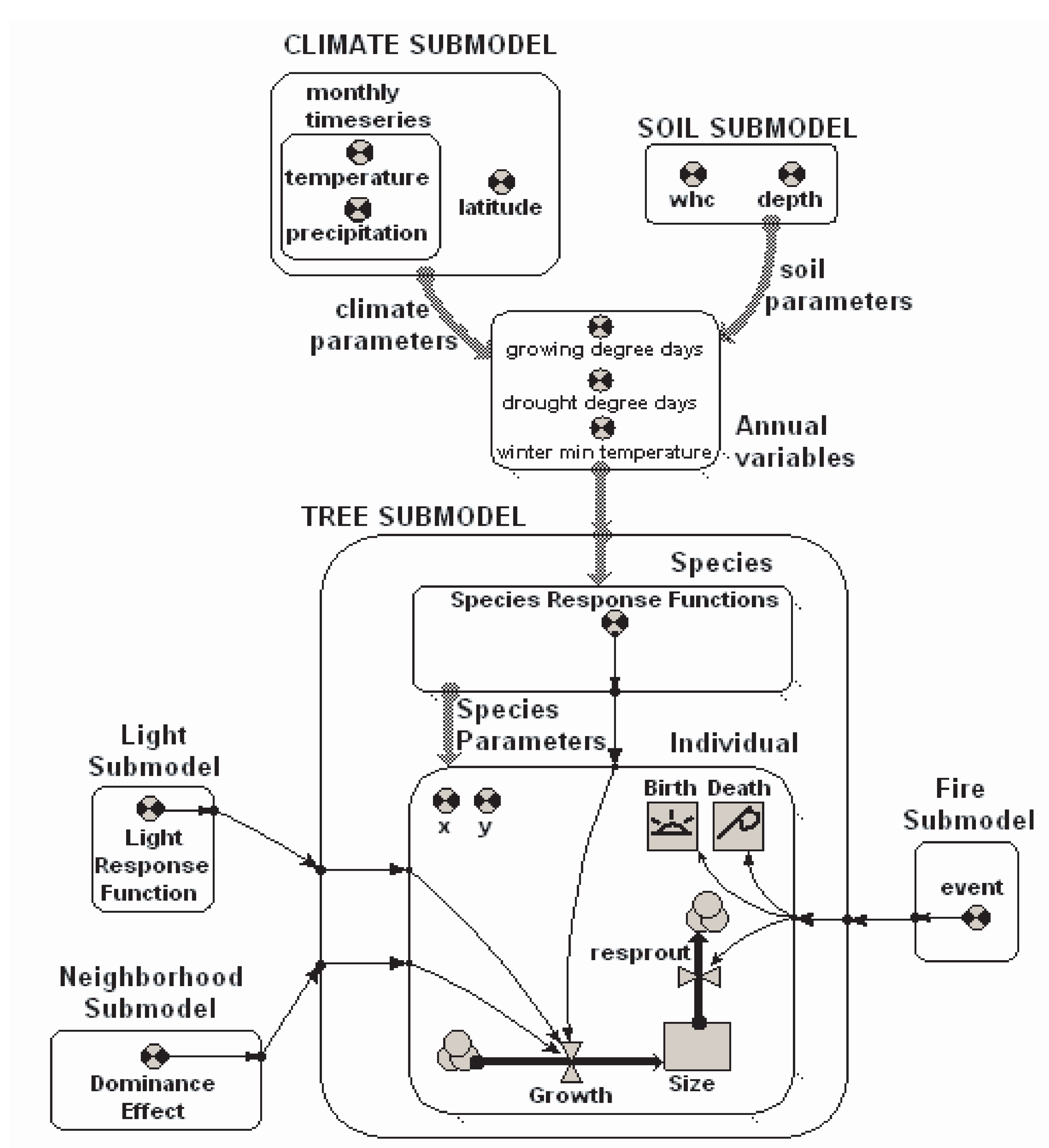


Figure 1: Visual Represantation of GREFOS structure

Table 1: Main Processes and Modification applied to GREFOS

Process	Method	Modification	References
Regeneration	Life History Strategies	Seeders, Fire Seeders, Facultative Seeders, Obligate Resprouters	(Kazanis & Arianoutsou 2004)
Growth	$H = a + b \cdot (1-e^{cD})$	Tree-shrubs life form with averaged maximum height	(Risch et al. 2005)
Mortality	a) FORCLIM's intrinsic b) FORENA's stress related mortality c) Fire events	Facultative Seeders 30% sprouting ability. Obligate Resprouters 80% sprouting ability.	(Solomon 1986; Bugmann 1994; Pausas 1998; Vesk & Westoby 2004)
Light Competition	FORCLIM's foliage allometric parameters	CO, DB, EB types	(Bugmann 1994)
Drought Effect	Modified Evapotranspiration Model	Calibration for five drought tolerance – avoidance classes	(Bugmann & Cramer 1998)
Dominance	Individual's Basal Area to Neighborhood's Basal Area ratio		

Study Area

The region of Krania (21:11E 39:51N) is situated in the prefecture of Grevena, Northwestern Greece. The elevation ranges from 800 to 1800 m above sea level. The mean annual temperature and mean annual precipitation are 10.7 ± 1.4 °C and 882 ± 228 mm; measured at the weather station of Krania (950m asl).

The dominant species are *Pinus nigra, Quercus frainetto and Abies borisii-regis* while *Alnus glutinosa, Platanus orientalis, Acer pseudo-platanus, Populus tremula, Ostrya carpinifolia, Fraxinus ornus* are also present (Vergos 1979).

Scenarios

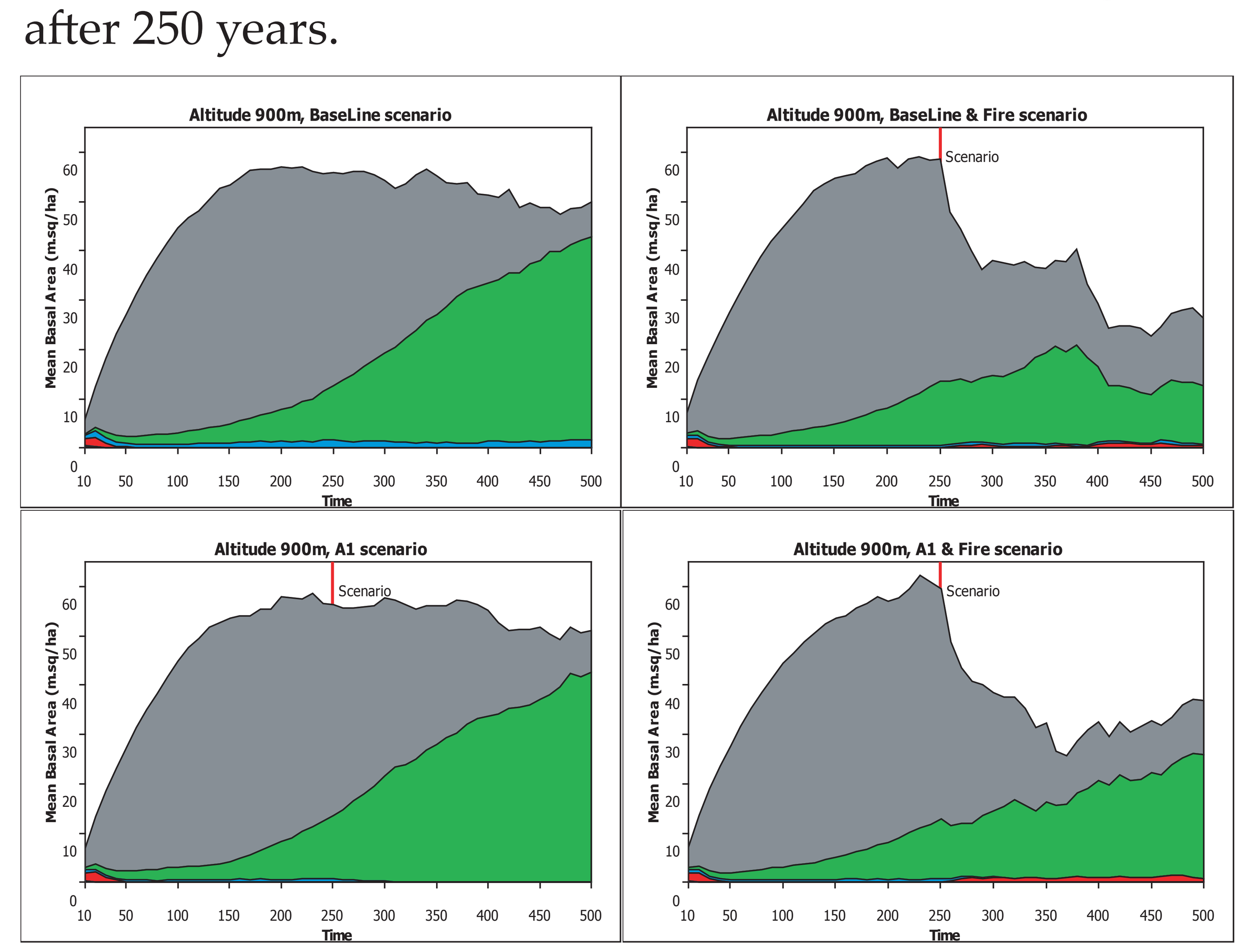
1. BaseLine (current climate)
2. BaseLine & Fire (current climate and increase in the fire frequency)
3. A1 (IPCC) climatic change (downscaled for the region of Krania)
4. A1 climatic change & Fire (same as A1 plus increased fire frequency)

Scenario	mean annual temperature (°C)	total annual precipitation (mm)	fire frequency (events / 100 years)
Baseline	10.7	887	0
Baseline & Fire	10.7	887	1
A1 climatic change (*)	14.9	756	0
A1 climatic change & Fire (*)	14.9	756	1

* Under climate change scenarios, a transient period of 100 years is following Mitchell et al. (2002) scalers. After the transient period the climate is stabilizing.

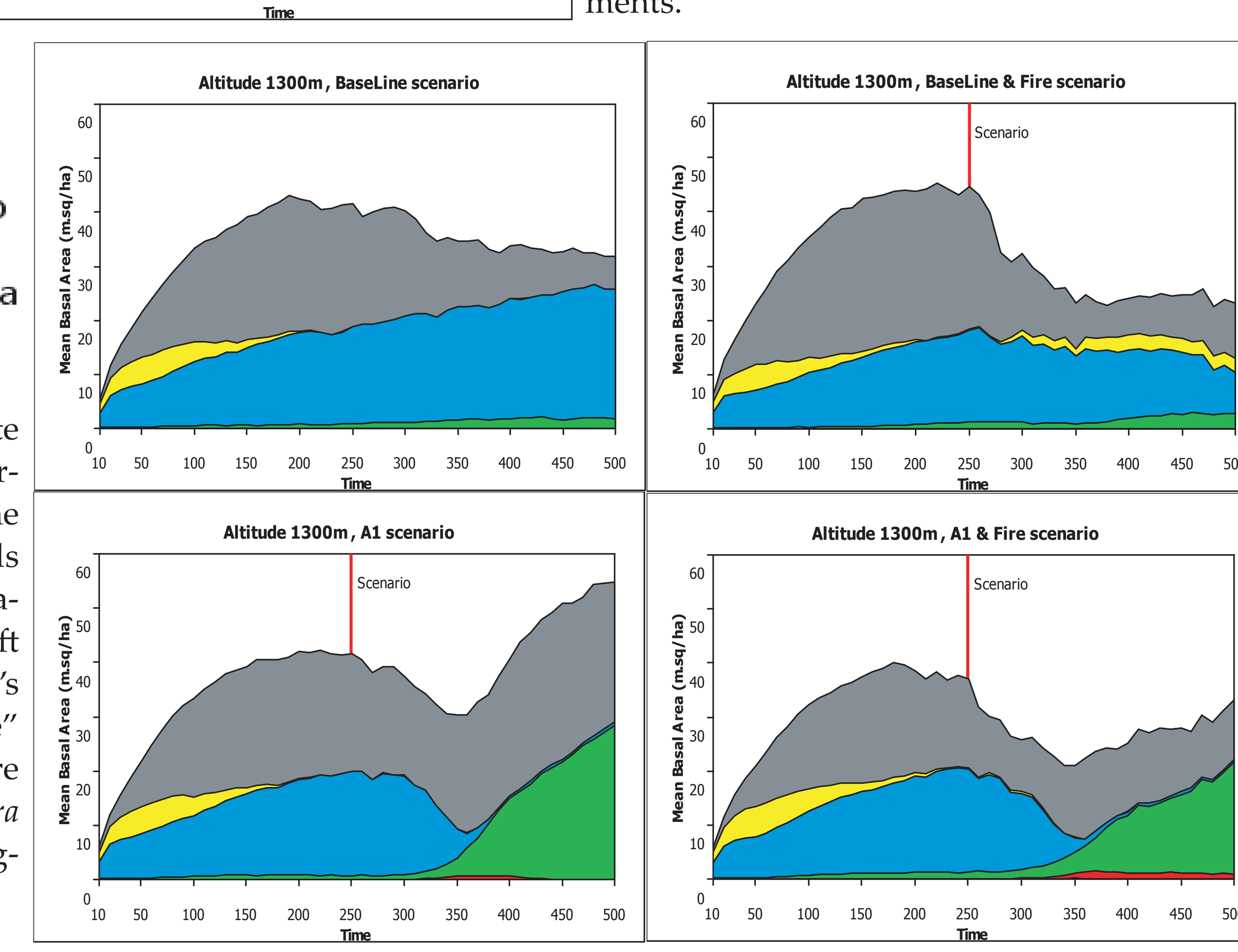
Simulations and Outputs

We run GREFOS for 500 years, 50 times (iterations) for each scenario at the altitude of 900m and 1300m. At the lower altitude the normal successional pathway is a *Pinus nigra* to *Quercus frainetto* vegetation change with low abundance of *Abies borisii - regis*. At 1300m *P. nigra* is replaced by *A. borisii*. Soil water holding capacity was kept constant at 120mm. Species pool was the same in all simulations and we did not enable new species to recruit in the stands. All simulations started from "bare ground" and change scenarios begun after 250 years.



At **lower altitudes (900m)** an increase in the frequency of fire events (BaseLine & Fire scen.) could prevent the "normal" pine to oak transition with a concurrent reduction of the productivity of the forest. Such type of vegetation changes have been noticed and are considered a result of *P.nigra* ability to grow vigorously in various altitudes (Quezel 1977). Climate change in both scenarios (no/with fire) results in the depression of the *A. borisii – regis* population and a gradual removal from the stands. No significant change in the abundance and dynamics of the two dominant species (*P. nigra* and *Q .frainetto*) is projected for "simple" climate change (A1 scen.) as both species are quite drought tolerant. When climatic change is followed by an increase in the fire frequency (A1 & Fire scen.) *Q. frainetto*, seems to perform better, as a result of its resprouting ability and higher heat requirements.

Figure 2: Output from GREFOS for the control (Baseline) and potential change scenarios. Y-axis represents total species basal area in square meters per hectare. The red line illustrates the starting point for each scenario.



At the **altitude of 1300m** the effect of climate change is more obvious. At this altitude "normally" Abies dominated stands (BaseLine scen.) could shift to mixed Pine – Oak stands (A1 scen). When climatic change is accompanied with fire (A1 & Fire scen.), the same shift is projected with a reduction of the forest's total biomass. In the case of a "simple" increase in the fire regime (BaseLine & Fire scen.), *A. borisii* is still dominant but *P. nigra* and *Q. frainetto* increase their abundance significantly.

Conclusions

Vegetation transition zones may be particularly vulnerable to changes in climatic patterns (Malanson & O'Leary 1995). In the transition zone from Mediterranean to Temperate climate, species "belonging" to the former drier level are expected to shift their altitudinal limits, if climate change is to increase the annual drought stress. Furthermore an increase in the fire frequency, as an "accompanying" result of the drier conditions, could favor species characterized by strategies adapted to fire (resprouting, fire seeding).

References:

Bugmann H. (1996) A Simplified Forest Model to Study Species Composition Along Climate Gradients. Ecology, 77, 2055-2074

Bugmann H. & Cramer W. (1998) Improving the behaviour of forest gap models along drought gradients. Forest Ecology and Management, 103, 247-263

Kazanis D. & Arianoutsou M. (2004) Long-term post-fire vegetation dynamics in *P. halepensis* forests of Central Greece: A functional group approach. Plant Ecology , 171, 101-121

Malanson G. & O'Leary J. (1995) The coastal sage scrub- chaparral boundary and response to global climatic change. In: (eds. Moreno J & Oechel W), pp. 203-223

Mitchell T.D., Hulme M. & New M. (2002) Climate data for political areas. Area, 109-112

Pausas J.G. (1998) Modelling fire-prone vegetation dynamics. In: Fire and Landscape Ecology (ed. L. T). International Association of Wldland Fire.

Quezel P. (1977) Forests of the Mediterranean basin. In: Mediterranean forests and maquis: ecology, conservation and management., pp. 9-32. MAB Technical Notes 2. Unesco.

Risch A.C., Heiri C. & Bugmann H. (2005) Simulating structural forest patterns with a forest gap model: a model evaluation. Ecological Modelling, 181, 161-172

Shugart H.H. (1984) A theory of forest dynamics. Springer-Verlag.

Solomon A. (1986) Transient Response of Forests to CO2 - Induced Climate Change: Simulation Modeling Experiments in Eastern North America. Oecologia, 68, 567-579

Vergos S., (1979) Strukturen und entwicklungsdynamik naturlicher schwarzkiefernwalder in Nordwest-Griechenland, Dissertation, Gottingen

Vesk P.A. & Westoby M. (2004) Sprouting ability across diverse disturbances and vegetation types worldwide. J Ecology, 92, 310-320