The Estimation of the Climate Change Impact on the *Eucalyptus globulus* and *Pinus pinaster* NPP using the FOREST-BGC

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Abstract

The FOREST-BGC was used to estimate the changes on the Net Primary Production (NPP) in a *Eucalyptus globulus* and a *Pinus pinaster* forests, in North of Portugal, considering periods of simulation of 1 and 20 years. The Meteorological Institute of Portugal (MIP) has described a few number of climate change scenarios for Portugal. Temperature and precipitation were changed, according some of the scenarios proposed by the MIP. The NPP estimated for the unaltered climate data was compared with the NPP estimated changing only temperature, only precipitation, and changing both. Available climate data from 2001 was used for compute those simulations. The results showed that the changes in temperature had a greater impact on the NPP. The gap of time considered for simulations was also not irrelevant.

Key words: NPP, Climate Change, *Eucalyptus*, *Pinus*

1 Introduction

Global warming hit the headlines for the first time in the summer of 1988, following heat waves and drought affecting North America (Christiansen, 2003). As mentioned by Running (1994) under the term "global change" a variety of physical, biological, and socio-economic changes are now taking place throughout the planet that will influence the biosphere in ways that can only be projected. That way simulation models present the ideal tool for dealing with this issue in general

An huge amount of climate change scenarios have been reported, like the one proposed by Pastor and Post (1988), referring that general circulation models suggest a 2 – 4 ºC mean rise in global temperature with CO_2 doubling with greater warming in higher latitudes than near the equator. Chapin III *et al*. (2000) report that the average surface air temperature has increased 0.3ºC during the twentieth century in the North America in the past 20 years. For Portugal, the National Meteorological Service (PNMS, 2000) has analysed the evolution of weather in Portugal, from 1868 till 1998. They realised that during the previous 100 years temperature has increased an average of 0.0074ºC/year. In terms of precipitation things were not so clear, however was found a general tendency for a decreasing of the total precipitation. March was the month where this decreasing was more visible (0.29 mm/month).

The main goal of this research is to predict the impact of different climate change scenarios on the *Eucalyptus* and *Pinus* net primary production located in the North of Portugal, using the FOREST-BGC, a well-known ecophysiological production model. Simultaneously, two periods of simulation will be tested: a short one with only one year, and a larger one with 20 years of simulation. This way will be analysed the impact of this time factor.

2 Study area

The *Eucalyptus globulus* stand, used for this simulation, is located in Aboim, near Amarante, on the way to Porto and the Atlantic Ocean. The Aliança Florestal manages this stand. This stand has in 2001, an average age of 7 years old, an average number of trees per hectare of 1169 and an average diameter at breast height of 11.1cm.

The *Pinus pinaster* stand is located in the North of Vila Real, between Boticas and Chaves. This stand has in 2001, an average age of 35 years old, an average number of trees per hectare of 1062 and an average diameter at breast height of 21.9cm.

3 Methodology

The tested scenarios were constructed based on a previous study of the PNMS (2000), for Portugal. Thus, excluding scenario 0 where actual climate is used with no changes, and used as comparison, three scenarios were tested:

- Scenario 1: the mean annual temperature increases 0.0074 ºC each year and total annual precipitation remains unaltered.
- Scenario 2: the mean annual temperature remains unaltered and total annual precipitation decreases 0.29 mm/month (assuming that the scenario of the worst month will repeat during the complete year).
- Scenario 3: the mean annual temperature increases 0.0074 ºC each year and the total annual precipitation decreases 0.29 mm/month.

Climate data from 2001 (from the meteorological station of Marão) was extrapolated for the center of the *Eucalyptus* study area, using MTCLIMAT. The same procedure was followed for the *Pinus* area but using data from the Vila Real meteorological station. A simulation of NPP for each scenario was done using FOREST-BGC.

4 Results

Results from all the simulations at the end of the first year of simulation are presented in Table 1 according to the scenarios previously defined.

For the *Eucalyptus*, analysis of Table 1 allowed to conclude that temperature changes have a higher impact on its production than changes in precipitation. The higher the increase in temperature, the lower the production of these ecosystems. The tested changes in precipitation had only a minor impact on the photosynthetic process in this species. The *Eucalyptus* stand is located in an area with high values of precipitation and mainly because of that the analysed decrease in precipitation was not sufficient to induce a hydrologic deficit, which would undoubtedly cause a greater impact. Temperature, on the contrary, is a key variable for the photosynthetic process because the higher temperature values coincide with the summer period, when the water available is lower. Therefore, increases in temperature will lead to higher levels of transpiration and, thus a decrease in the potential of photosynthesis in trees.

For the *Pinus* and from Table 1 it can be concluded that once again temperature is the most important variable. However, changes in precipitation produced a higher impact in this species than in the *Eucalyptus* ecosystems. The impact of simultaneous changes in rainfall and temperature produces an added effect since changes in both variables have a higher impact than changes in individual variables only.

Table 1 NPP (kg ha^{-1} $year^{-1}$) obtained from the tested scenarios proposed by the PNMS (2000) in the first year of simulation.

		Eucalyptus		*Pinus*	
		TEMPERATURE		TEMPERATURE	
		Unaltered	↑0.074ºC/year	Unaltered	↑0.074ºC/year
RAIN FFALL	Unaltered	14693	14686 *(↓0.05%)*	17747	17738 *(↓0.05%)*
	↓0.29mm/month	14692 *(↓0.01%)*	14685 *(↓0.01%)*	17745 *(↓0.01%)*	17735 *(↓0.07%)*

The next goal consisted in verifying whether the previous conclusions had not change at the end of the twenty-year period of simulation. Table 2 shows the results obtained. From their analysis, even if the main conclusions were still correct, some new facts arise and merit discussion.

Table 2 Accumulated NPP (kg ha^{-1}) obtained from the tested scenarios proposed by the PNMS (2000) after 20 years of simulation.

		Eucalyptus		*Pinus*	
		TEMPERATURE		TEMPERATURE	
		Unaltered	↑0.074ºC/year	Unaltered	↑0.074ºC/year
RAIN FFALL	Unaltered	110346	109089 *(↓1.3%)*	133282	131666 *(↓1.2%)*
	↓0.29mm/month	109344 *(↓1.1%)*	107989 *(↓2.3%)*	131278 *(↓1.5%)*	129746 *(↓2.7%)*

As for the *Eucalyptus* ecosystems, the first new fact arises from analysis of the importance of changes in temperature and rainfall and their impact on the *Eucalyptus* growth. Despite the fact that temperature is still the most relevant factor affecting *Eucalyptus* photosynthesis, on a longer term scenario, the importance of precipitation has also increased. When both variables are changed together, the final impact on production is the sum of each one of them, when tested in an individualised way.

For the *Pinus*, changes in rainfall constituted the most important factor affecting production in those ecosystems and, once again, when both variables changed, the final impact resulted from the sum of both individualised variables. Taking into consideration this wider time period, it appears that the final impact of changes of each variable has resulted from the sum of each individualised impact.

For both species, the impact of changes were always greater at the end of 20 years of analysis than at the end of the first year of analysis. That means, even if some analysis can already be outlined from a short period of simulation, the relevance of those changes cannot be derived from that short time period. Time represents a very important factor in this kind of study. It is important to determine whether the ecosystems have started reacting to climate change immediately.

5 Final remarks

The first major conclusion is the most limiting factors for production are temperature changes for the *Eucalyptus* and rainfall for the *Pinus*. A greater increase in the average temperature value would produce a greater decrease in production for both stands. An increase of 4°C in the average temperature will reduce production in around 7% for both species, if rainfall does not change.

In terms of rainfall things were not so linear. However, there was always a decrease in production when total precipitation decreased. If temperature does not change and rainfall decreases by 15% the *Eucalyptus* production will decrease by around 1% and the *Pinus* by 3%. Given the different water requirements of each species the fact that the *Eucalyptus* stand is located in a site with higher rates of rainfall implies that the tested decrease in rainfall does not create a great hydrologic deficit. The same does not happen with the *Pinus* area, with lower rates of rainfall, despite the soil revealing a greater capacity to preserve the available water. In both situations an increase of temperature will cause a decrease in production.

The achieved results are in line with those found by Cao and Woodward (1998). Those authors found that production for the Temperate forests will decrease by around 12% if atmospheric CO_2 does not change and climate change is taken into consideration only. In this particular case the worst scenarios have conducted to a decrease of 13.3% for the *Eucalyptus* and 14,1% for the *Pinus*, but only if temperature decreases by 7°C during the next century, an extremely pessimist assumption. If temperatures increase is only 4ºC that means NPP will only decrease by around 7% for both ecosystems

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