Article

I think different: Models of climate warming impact on plant species are unrealistic

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Received 4 March 2012; *Accepted 9 April 2012*; *Published online 5 June 2012*
IAEES

Abstract
Although studies about climate change impacts on plant species are often published on prestigious journals, in particular when they deal with broad areas and numerous species, in this manuscript I advance my doubts on their methodological robustness and, as a consequence, on their results. In particular I focus my attention on two major drawbacks, i.e. the need for a) nonlinear community-based models instead of species-based ones, and b) for the replacement of the potential niche with the future niche in predictive models.

Keywords biotic interactions; climate change; future niche; plant communities; plant species; system dynamics.

1 Introduction

Climate change at global and regional scale is mainly concerned with the increase of temperature (IPCC, 2001a, b; Zhang, 2009; Zhang et al., 2010; Zhang and Liu, 2012), and is likely to result in a globally-averaged increases of 1.4-5.8 °C by 2100 in comparison with 1990. Changes in climate are expected to shift the distribution of plant species along environmental gradients if their current environmental tolerance is exceeded (Miller and Urban, 1999). IPCC (2001b) remarked that future climate change is estimated to exacerbate the loss of species, especially those species with strict climate and habitat requirements, and limited migration capabilities. Thomas et al. (2004) predicted that 20-50% of all endemic plant species of Europe may be committed to extinction by 2050. Mountainous areas, with cold climate of alpine type, are those more interested by changes in the species distribution (Körner, 1999), generally by means of a rising in altitude. Such a process could alter the plant biodiversity (Thuiller et al., 2005), by bringing new species to areas where before are absent (Malcolm et al., 2002), and determining the increase or the decrease in abundance with consequent population extinction at the lower altitudinal range limit of mountain-top species (Walther et al., 2002; Parmesan and Yohe, 2003).

Although studies on climate change impacts on plant species are often published on prestigious journals, in particular when they deal with broad areas and numerous species, in this manuscript I advance my doubts on their methodological robustness and, as a consequence, on their results. In particular I focus my attention on two major drawbacks, i.e. the need for a) nonlinear community-based models instead of species-based ones, and b) for the replacement of the potential niche with the future niche in predictive models.

2 Pitfall 1: Plant Species Are Not Alone in Apace and Time

The impact of climate warming on plant species is commonly estimated as follows: *climate warming scenario → direct impact on single species*. A paradigmatic example can be found in Engler et al. (2011) who consider the impacts across all major European mountain ranges of climate change on 2632 plant species considered independently in space and time.

Unfortunately, local biotic interactions among plant species complicate the broad-scale control that climate has on species dynamics. All species are embedded in complex networks of interactions with other organisms, and the ways in which climate change works across the whole community is much more complex than the simple direct effects on single species. Temperature increase scenarios may cause unobvious alterations to the network of interactions among species. The indirect effects that are susceptible to global change and the complex feedbacks that exist among species (Suttle et al., 2007) implicate that species-specific projections are not necessarily consistent with those of their communities, and it's also likely that unexpected results happen due to nonlinear and counterintuitive community dynamics. Therefore, a full understanding of the effects of T° increase scenarios on plant communities necessarily requires the consideration of the whole interaction network among species. This involves a methodological approach as follows: *climate warming scenario → direct impact on each species → indirect impacts on all linked species → feedback impacts at community level.* It's clear that this kind of approach can only be solved using systems of differential or difference equations, which allow to take into account both direct effects on single species and all the complex feedbacks among species. The parameters of such equations could be determined through *in situ* experiments specifically for each study area, or through laboratory experiments where T° increase is accelerated and parameters are extracted specifically for each species. However, if precise predictions are not a requirement, I suggest that qualitative models of community dynamics (e.g. loop analysis) could offer an alternative and cost-effective method for predicting plant species responses to climate warming. A qualitative approach would provide predictions on the probable direction of change in species abundances, and would be suitable if only the direction of the effects of climate perturbations is required, not their magnitude. The strength of this approach would be in its generality, and its ability to address the complex, nonlinear effects that feedbacks among species determine on single species and on the whole network of species.

3 Pitfall 2: Future Niche Is Different from Potential One

The second drawback I want to emphasize deals with a very common methodological approach where the impact of climate warming on plant species is measured over the actual niche and the potential one, following the next scheme: *climate warming → impact on actual and potential niches*. A paradigmatic example can be found again in Engler et al. (2011).

This approach assumes that plant species are able to migrate from actual niche and occupy the whole potential niche. But, is this assumption realistic? No, of course. It could be true for plain areas with no topographic barriers. But mountain or hill landscapes, where the effect of climate warming is much more important than in lowlands, are topographically complex and most species are limited in their migration capabilities by topographic patterns and wind behaviors. As a result, future niche for most species is just a small portion of the potential niche, regardless of how they move (winds, insects, water and so forth). Thus the realistic and correct version of the previous scheme would be: *climate warming → impact on actual and future niches*

It's clear that this step forward requires a modellistic effort in order to individuate the future niche from the actual one. For instance the most of the species in mountain areas move through wind energy. The most of alpine species utilize wind transport for diaspore dispersal, and more than 90% are anemochorous (van der Pijl, 1982). Thus, a wind model of seed dispersal is strictly required to estimate future niche from actual one. I understand that such approach is much more difficult than the simple use of potential niche. In fact, although potential niche modelling still needs further methodological improvements, it can be considered a well-developed topic in conservation ecology. Instead, future niche modelling is still an open research field, with great difficulties in data sampling (e.g. seed dispersal distances, wind velocity of seed release etc.) and model validation, but it's the only way to a realistic assessment of climate warming impact on plant species, and to a correct survival probability estimation.

4 Conclusions

Studies on the impacts of climate warming on plant species are usually realized by botanists who have a deep and precious knowledge of the behavior of single species in the face of climate change, but unfortunately lack the capability of a) conceptualizing the overall effects at community level, and b) estimating the effective chance of plant species to migrate from their actual niche. These two further steps are absolutely necessary, and strictly require the cooperation with a further professional figure, i.e. environmental analysts and modelers. Unfortunately, the most of actual studies lack this cooperation and, as a result, they are wrong in the conceptual and methodological approach, and thus unrealistic in their results. Although these studies are often published on prestigious scientific journals, they only have the fortune that can't be validated because they are usually projected to 2050 or even 2100. Thus I offer a simple challenge to botanists: make your projections to 2015 or 2020 in your studies, not 2050 or 2100, so that the comparison of your results with the real world ones will soon demonstrate whether these projections are realistic or not.

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