

PhD project

Linking forest management and species distribution models: a theoretical approach under climate change

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Abstract

Abstract section

Ecology may provide many of the answers — but only if it is holistic enough to incorporate the human element as part and parcel of the ecosystem.

(Pfister, 1993, p. 231)

1 What is going on?

Climate change is an increasing trending topic both in non-scientific (Capstick et al., 2015) and scientific environment (Figure 1), transforming our world as a metamorphosis of practice and acting (Beck, 2016). According to IPCC (Cubasch et al., 2013), humans activities are contributing to increase the concentration of greenhouse gases, which can lead to increase the mean temperature and the strength of extreme climate events. This global change has an impact in different biological processes, from local species constraints (e.g. low regeneration Treyger and Nowak, 2011), shift in species' range (Boisvert-Marsh et al., 2014; Monleon and Lintz, 2015) and in community composition (Dieleman et al., 2015) to range retractions and extinction (Thomas et al., 2006), impacting biodiversity at different scales (Peñuelas et al., 2013).

Species distribution models (SDM; defined in section 6) has predicted tree species' range shift under climate change, providing a wide range of applications, as in biodiversity conservation and management (Guisan and Thuiller, 2005; Guisan et al., 2013). However, these models are generally phenomenological and distributed at equilibrium with climate (e.g. Pigot and Tobias, 2013). Hence, they do not consider important determinants of range limits as demography (Louthan et al., 2015), ecological constraints (Wisz et al., 2013; Pigot and Tobias, 2013) and species absences data (Koshkina et al., 2017), inducing non-accurately projection of the future spatial

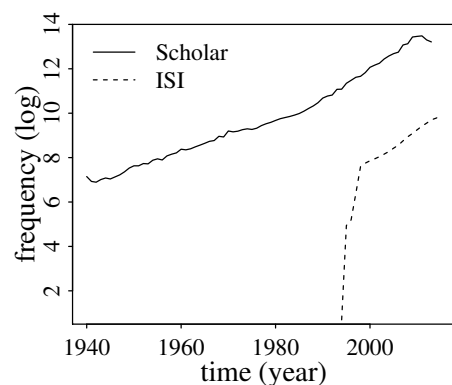


Figure 1: Frequency of the keyword “Climate change” used in references indexed on Google Scholar (1940 - 2013) and Web of Science (1994 - 2015)

distribution of a species (Tavecchia et al., 2016). Considering then ecological constraints, trees' migration rate following climate change will be slower than predicted (Bertrand et al., 2011; Sittaro et al., 2017), increasing the climatic debt (Bertrand et al., 2016).

The climatic debt is a measure of the lag (or disequilibrium) of plant communities with climate change, integrated in an environmental context (Bertrand et al., 2016). Essl et al. (2015) has listed twelve mechanisms that contribute to delayed biodiversity responses, among them, changes appears at ecosystem (loss and degradation), community (secessional, biotic interaction, species removal and invasion) and population (evolutionary and adaptive) levels. Disturbance regime was also listed but it may not be related to climate debt (Bertrand et al., 2016). Therefore, this lag under climate change promotes extinction debt, being a challenging for biodiversity conservation (Kuussaari et al., 2009) and productivity (Lasch et al., 2002). Then identify the mechanisms shaping delayed biotic response of systems to environment, its resilience as well as alternatives to mitigate ecological constraints, is crucial to assess the vulnerability of biodiversity to climate change and improve forecasts and biodiversity management (Essl et al., 2015; Oliver et al., 2015; Bertrand et al., 2016).

2 Preliminary objectives

I call this section as “preliminary” because I am still trying to figure out possible gaps I will be interested in working on. I also believe that classifying my plan as preliminary will help me identify throughout my thesis the “best” route to finish it in a pleasurable and creative way.

The main objective of my thesis is to create a decision make tool to improve management strategies that take climate change into account.

3 Mitigating ecological constraints

Ecological constraints, together with abiotic and biotic factors, act at different scales, being difficult to track and hence to mitigate. To start, our work aims to identify how we can increase forest resilience, or more specific, how to decrease the time needed to recover from a disturbance (theory described in section 4). Here, I present some possible topics that I will be testing through my thesis using SDM, acting both at local and large scale.

Forest management

Present some motivations, advantages and disadvantages in considering forest management.

Four major strategies are available to mitigate carbon emissions through forestry activities: (i) to increase forested land area through reforestation (6), (ii) to increase the carbon density of existing forests at both stand and landscape scales, (iii) to expand the use of forest products that sustainably replace fossil-fuel CO₂ emissions, and (iv) to reduce emissions from deforestation and degradation. in Managing forests for climate change mitigation (Science)

<http://onlinelibrary.wiley.com/doi/10.1111/j.1752-4571.2010.00157.x/full> <http://www.sciencedirect.com/sci>

Interesting argument about who should peak do winners from [Webster et al. \(2017\)](#). They say that *Predict-and-prescribe management may erode diversity by focusing on ‘winners’*.

Forest management in a theoretical view was actually not very much explored and so I consider it a kind of gap we should better explore. Read [Becknell et al. \(2015\)](#) for an overview.

Species interaction

Biotic and abiotic species mechanisms

4 Theoretical approach

Read the section *recent developments in predicting changes in species distribution* from [Ehrlen and Morris \(2015\)](#)

Disturbance

Pass through the main disturbance theories basing mainly in [Pulsford et al. \(2016\)](#)

Resilience

A classical definition of resilience in ecology is the ability of ecosystems to absorb changes and still persist ([Holling, 1973](#)). The concept was further developed in other context (e.g. social-ecological systems), and a more contemporary definition considers resilience as (i) the amount of disturbance the system can absorb, (ii) the degree the system is able to self-organize and (iii) the degree of learning capacity to adapt to disturbance ([Cumming, 2011](#)). In other words, resilience is basically external changes accommodated (or absorbed) that do not modify ecosystem structure ([Folke et al., 2002](#)) or the resistance of a particular ecological state to change ([Peterson et al., 1998](#)). Resilience can be increased by multiple factors as, but biodiversity shows to be crucial to maintain long-term resilience of ecosystem services ([Oliver et al., 2015](#)).

It is also important to not confuse resilience with stability of a system. Resilience is the rate and extent of recovery of a system while stability is the moment the system stops to change over time. Before introduce the method to calculate resilience, we must have an idea of what is the equilibrium ([Box 1](#)) and stability ([Box 2](#)) of a system.

(iii) But how to calculate it in a analytical way? Now introduce the calculus of λ by Jacobian matrix.

Box 1. Equilibrium

$$E = mc^2 \qquad \text{Formula of the universe} \qquad (1)$$

Box 2. Stability

$$E = mc^2 \qquad \text{Formula of the universe} \qquad (2)$$

Range dynamics theory

What theories can help us to describe species range under climate change?

How to integrate forest management in this theory?

-> Matapopulation dynamics theory <-

Transition period - Alternative Stable States?

Species Interaction: why is it important?

Explain the role species interaction can play on its distribution range. <http://www.sciencedirect.com/science/art>

The perceived threat of climate change is often evaluated from species distribution models that are fitted to many species independently and then added together. This approach ignores the fact that species are jointly distributed and limit one another ([Clark et al., 2014](#)).

Joint species distribution?

Interactions between land-use and climate also can underestimate species resilience in distribution models ([Goring and Williams, 2017](#)).

5 Study case: the Quebec forest resource

Explain here where I am going to work and also why I am choosing this area.

6 Methods

Here we see a briefly presentation of possible methods will be used in the thesis.

Modeling

Why and how modeling?

Morin et thuiller 2009:What then are the best strategies for obtaining accurate predictions for changes in the distributions of deciduous temperate trees? At the scale of the geographic distribution of species, no experiments in situ can be reasonably carried out to predict possible range shifts (Woodward 1987). Modeling therefore appears the most feasible and efficient way to establish useful predictions (Lovejoy and Hannah 2005, Thuiller 2007), and several kinds of models have been developed during the previous decade for this purpose. As reviewed by Midgley et al. (2007), these models fall into two main classes: vegetation-type models (dynamic global vegetation models [DGVMs]) and species-specific models (niche-based and process-based).

Species Distribution Models

Nice resume about SDM in [Morán-Ordóñez et al. \(2016\)](#).

Integral Projection Models

I should be writing and not playing with \LaTeX

Bayesian approach

I should be writing and not playing with L^AT_EX

7 Thesis structure

The first part of the thesis will be a general introduction in French where I will probably use a part of this document and present the big picture of my thesis.

The first chapter will try to answer the question *Can forest management increase forest resilience to climate change?*. The paper will work with an analytical and sensitivity analysis in a metapopulation dynamics model to understand the impact of forest management on increasing forest resilience.

In the second chapter I am going to build a landscape model that will consider both forest management and species interaction.

The third chapter I am going to build another model but in a local scale. *I have to find a good biological reason for that.*

The fourth chapter will then integrate both landscape and local model into one. Here I will also track the uncertainty of the model by bayesian approach.

TODO:

- Automate box labels
- Short reference style

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