Difficult transition for sugar maple in Boreal forest under climate change? Impact of plant-soil feedback on Sugar maple migration.

Research proposal

Master in Wildlife management

By

Steve Vissault

For

Richard Cloutier, Pr.
Director of the program committee

Dominique Arsenault, Pr.
President of the jury

Unknow, Pr.
External member of the jury

Matt Talluto, PhD
Research Co-director

Dominique Gravel, Pr.
Research Director

Université du Québec à Rimouski
November 26, 2013

Introduction. Many ecotone studies and modeling efforts on transition between forest to non-forest ecosystems [12, 11, 5] but little attention has been given to evaluate the transitionnal dynamics of forest-forest ecotone [3, 4]. Ecotones most present in Quebec consists of a transitionnal area with intermixed fragments of boreal forest and northern temperate forest[3]. This area is hypothesized to shift in the coming decades due to the climate change [12]. Indeed, this zone is of particulary concern as it contains species pushed to their physiological limits, generating a zone sensitive to environmental fluctuations such as those from a climatic change [8, 3]. The boreal region is warming twice as fast as the global average and will inevitably alter interaction and composition in the community [12, 6]. Hence, we expected this area is undergoing significant natural pressures (e.g. fire regime) increasing in frequency and severity in the coming decades and inducing profound changes due to climate change. Many species of the boreal-temperate forest ecotone are expected to expand or reduce their distribution [4, 2, 6] modifying the composition and the dynamic of this ecotone.

Most phenomena in ecology occurs often gradually over the time [11].

Our hypothesis proposes the presence of alternative stable states in the transition zone between the temperate and boreal forest as a result of the progression difficulty. Under pressure from the same climatic conditions we would expect to find in boreal-temperate forests ecotone, the alternative stable states consisting of forest patches dominated by balsam fir and an another by sugar maple at same environnemental conditions

Sugar maple is one of the most representative species of northern temperate forests [4, 8, 7]. Currently some patches have been established in the boreal landscape and in the coming decades this species is expected to continue to extend its range [4, 2, 13]. This northward migration will result in increasing the surface of the ecotone between the boreal and temperate forest of Quebec. The expansion of sugar maple distribution could be difficult and explain by the fact than microclimatic conditions found in boreal forests are different from those present in temperate forest. Colder temperatures from shading and excess soil moisture due to snow melt cause litter to be more acidic and fibrous during the spring. Therefore, even if the regional climate conditions are favorable [7], the microbiota conditions found in the boreal forest could affect the establishment of sugar maple [7, 9, 1]. In this case, the sugar maple could be unable to migrate in boreal forests as a result of climate change. This hypothesis correspond with the observations of Zhu *et al* (2012) who revealed than only 4.3% of migrations are consistent with expansion[14].

Objective. This project aims to determine whether alternative stable states are present in the temperate-boreal forest ecotone and if so, look at the impact of plant-soil and disturbances feedback on the alternatives stables states. To assess this main objective, we will (O1) generate a transitionnal model between the temperate and the boreal forest; (O2) study the equilibrium states based on the model; (O3) investigate the spatial structure of the transitonnal zone; and finaly (O4) run simulations based on different climate change scenarios.

Methods.

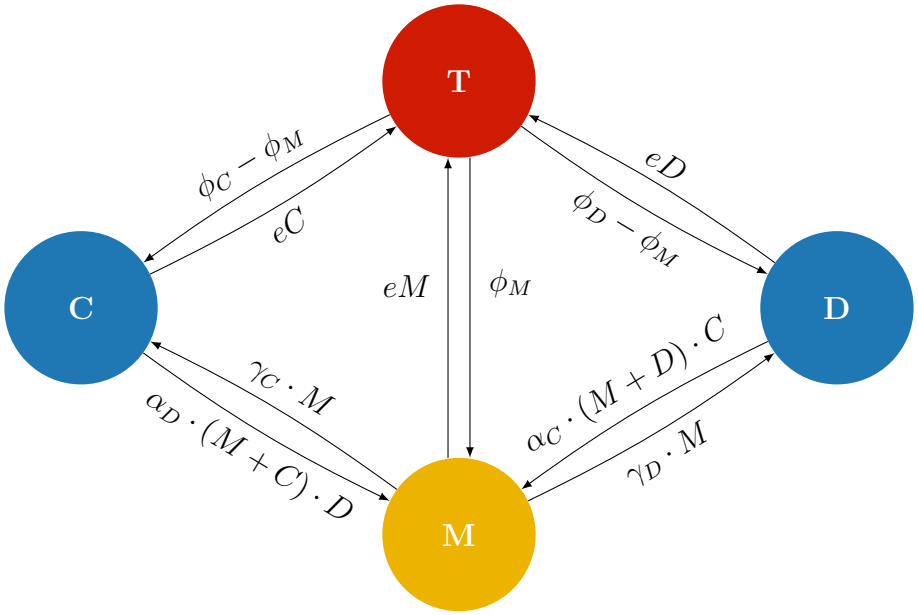

Figure 1: Conceptual transition model between forest stands deciduous (D), mixte (M) and coniferious (C). T corresponds to a transitionnal state where a perturbation are occurred with a frequence of e. ϕ, γ and α are referred as the recovery, the colonisation and the succession rates respectively. We defined the recovery rate as $\beta_C \cdot (M + C) \cdot E = \phi_C$ and also $\beta_D \cdot (M + D) \cdot E = \phi_D$, to get finaly $\phi_M = \phi_C \cdot \phi_D$

Definition of terms

Ecotone: Livingston (1903) defined an ecotone as a zone of tension between forest ecosystems [3].

Alternative stable states: An alternative stable state is described as contrasting states in which a system may converge under the same external conditions [10]

References

[1] P. De Frenne, F. Rodríguez-Sánchez, D. A. Coomes, L. Baeten, G. Verstraeten, M. Vellend, M. Bernhardt-Römermann, C. D. Brown, J. Brunet, J. Cornelis, G. M. Decocq, H. Dierschke, O. Eriksson, F. S. Gilliam, R. Hédl, T. Heinken, M. Hermy, P. Hommel, M. a. Jenkins, D. L. Kelly, K. J. Kirby, F. J. G. Mitchell, T. Naaf, M. Newman, G. Peterken, P. Petrík, J. Schultz, G. Sonnier, H. Van Calster, D. M. Waller, G.-R. Walther, P. S. White, K. D. Woods, M. Wulf, B. J. Graae, and K. Verheyen, *Microclimate moderates plant responses to macroclimate warming.*, Proceedings of the National Academy of Sciences of the United States of America, (2013), pp. 1–5.

[2] D. Goldblum and L. Rigg, *Tree growth response to climate change at the deciduous boreal forest ecotone, Ontario, Canada*, Canadian Journal of Forest Research, 2718 (2005), pp. 2709–2718.

[3] D. Goldblum and L. S. Rigg, *The Deciduous Forest - Boreal Forest Ecotone*, Geography Compass, 4 (2010), pp. 701–717.

[4] N. Graignic, F. Tremblay, and Y. Bergeron, *Geographical variation in reproductive capacity of sugar maple (Acer saccharum Marshall) northern peripheral populations*, Journal of Biogeography, (2013), pp. n/a–n/a.

[5] M. Hirota, M. Holmgren, E. V. Nes, and M. Scheffer, *Global Resilience of Tropical Forest and Savanna to Critical Transitions*, Science, (2011), pp. 232–235.

[6] L. Hughes, *Biological consequences of global warming: is the signal already apparent?*, Trends in Ecology & Evolution, 15 (2000), pp. 56–61.

[7] M. Kellman, *Sugar maple (Acer saccharum Marsh.) establishment in boreal forest: results of a transplantation experiment*, Journal of Biogeography, 31 (2004), pp. 1515–1522.

[8] Y. Messaoud, Y. Bergeron, and A. Leduc, *Ecological factors explaining the location of the boundary between the mixedwood and coniferous bioclimatic zones in the boreal biome of eastern North America*, Global Ecology and Biogeography, 16 (2007), pp. 90–102.

[9] J.-D. Moore, L. Duchesne, and R. Ouimet, *Soil properties and maple–beech regeneration a decade after liming in a northern hardwood stand*, Forest Ecology and Management, 255 (2008), pp. 3460–3468.

[10] M. Scheffer, *Critical transitions in nature and society*, Princeton studies in complexity, Princeton University Press, Princeton, 2009.

[11] M. Scheffer, S. Carpenter, J. a. Foley, C. Folke, and B. Walker, *Catastrophic shifts in ecosystems.*, Nature, 413 (2001), pp. 591–6.

[12] M. Scheffer, M. Hirota, M. Holmgren, E. H. Van Nes, and F. S. Chapin, *Thresholds for boreal biome transitions.*, Proceedings of the National Academy of Sciences of the United States of America, 109 (2012), pp. 21384–9.

[13] C. Woodall, C. Oswalt, J. Westfall, C. Perry, M. Nelson, and a.O. Finley, *An indicator of tree migration in forests of the eastern United States*, Forest Ecology and Management, 257 (2009), pp. 1434–1444.

[14] K. Zhu, C. W. Woodall, and J. S. Clark, *Failure to migrate: lack of tree range expansion in response to climate change*, Global Change Biology, 18 (2012), pp. 1042–1052.