Questions

- **speed and patterns of tree establishment across ecotone**
- what factors *accelerate* establishment across ecotone?
- what factors *slow down/hinder* establishment across ecotone?
- are some species increasing?
- are some species receding?

Key elements: speed (temporal), range shift (spatial)

Also:

- Seedling establishment beyond the range limit of adult trees can occur relatively rapidly
- transition of seedlings to saplings is a key first step for tree migration
- in many species, sapling range limit is further *south* than adults see Sittaro *et al.* (2017)
- compare transition from seedlings to saplings to trees -> bottleneck?

see D'Orangeville *et al.* (2018) for ideas (growth model with PEP, but could use similar variables, methods, figures?)

see Fisichelli *et al.* (2014) for simple example, but including temporal

see figures in Beckage *et al.* (2008) to compare seedlings/saplings/tree distribution?

Method

- Pourquoi seulement entre 2 périodes? pourquoi pas inclure toutes les périodes d'inventaire? pourquoi 2005-2018 (des années sont sorties depuis)
- Espèces

MySpecies <- c("ACERUB", "ACESAC", "BETALL","FAGGRA", "THUOCC", "ABIBAL", "PICMAR", "BETPAP", "POPTRE")

- région: je suggère de commencer par l'écotone seulement (sapinière à bouleau jaune) pour simplifier le problème (c'est le changement dans cette région qui nous intéresse le plus). Ensuite on peut élargir au reste du québec.
- pour les variables du sol, on peut aussi faire un indice composite (voir Drobyshev *et al.* (2014) et Mansuy *et al.* (2010)) en utilisant des infos à large échelle:
- Soil properties

- Indice d'humidité du sol
- Depot de surface
- dans biotic "Couvert" c'est quoi? si tu as déjà inclus "Total basal area"...
- variables climatiques? Climate Moisture Index
- model: matrix model?
  - Power *et al.* (2022)
  - msm R package?
  - https://academic.oup.com/forestscience/article/59/3/359/4583685
  - https://www.sciencedirect.com/science/article/pii/S0378112711004932?casa_token=tXWOC3L41ak
    BPFh436m36_Z03RorvbsauC2Kmkpv3oT5pjU48QPw

Références

Beckage, B., Osborne, B., Gavin, D.G., Pucko, C., Siccama, T. & Perkins, T. (2008) A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. *Proceedings of the National Academy of Sciences*, **105**, 4197–4202.

D'Orangeville, L., Houle, D., Duchesne, L., Phillips, R.P., Bergeron, Y. & Kneeshaw, D. (2018) Beneficial effects of climate warming on boreal tree growth may be transitory. *Nature Communications*, **9**.

Drobyshev, I., Guitard, M.-A., Asselin, H., Genries, A. & Bergeron, Y. (2014) Environmental controls of the northern distribution limit of yellow birch in eastern Canada. **44**, 12.

Fisichelli, N.A., Frelich, L.E. & Reich, P.B. (2014) Temperate tree expansion into adjacent boreal forest patches facilitated by warmer temperatures. *Ecography*, **37**, 152–161.

Mansuy, N., Gauthier, S., Robitaille, A. & Bergeron, Y. (2010) The effects of surficial deposit-drainage combinations on spatial variations of fire cycles in the boreal forest of eastern Canada. *International Journal of Wildland Fire*, **19**, 1083–1098.

Power, H., Auger, I., Guillemette, F., Raymond, P. & Dumais, D. (2022) Sapling growth dynamics after partial cutting in temperate mixedwood stands. *Canadian Journal of Forest Research*, **52**, 1186–1200.

Sittaro, F., Paquette, A., Messier, C. & Nock, C.A. (2017) Tree range expansion in eastern North America fails to keep pace with climate warming at northern range limits. *Global Change Biology*, **23**, 3292–3301.